Turning and Boring Practice

BOOKS

by

F. H. Colvin and F. A. Stanley

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TURNING AND BORING PRACTICE

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TURNING AND BORING PRACTICE

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Preface to the Third Edition

In preparing this edition we have taken the data originally appearing in the Wartime Supplement and placed it in the proper section of the body of the book. This makes it more readily accessible and avoids the confusion of having data on similar subjects in different places.

We have also added valuable data in various sections on mandrel and taper work in lathes, on precision boring where extreme accuracy is required, on boring bars for special work, and new data on carbide tools for different classes of work. We believe that both the rearrangement of material and the new data that have been included will add to the usefulness for practical men.

THE AUTHORS

NEW YORK, N. Y.
July, 1948

Preface to the First Edition

Modern machine-shop practice uses so many machine tools that it is impossible to discuss them all in one volume. It has therefore seemed best to include here those used in turning and boring operations. These tools comprise engine lathes, turret lathes, and lathes of both the automatic and the semiautomatic types as well as the three types of boring machines found in modern shop equipment. Following the elements of lathe work are given modern examples of turret and screw-machine work. This section is particularly complete as a guide to the way in which automatic screw machines operate and the methods by which they are tooled up for a variety of work.

Boring operations include machines of both the horizontal and the vertical type as well as the new single-point machines that have become established in the field where accurate work is necessary. This book not only shows the machines and the way in which the work is held but also gives data as to speeds and feeds.

Particular attention has been paid to new cutting alloys and to the new materials that the present-day shop man must know how to handle to advantage. Economical uses of the new alloys are discussed by well-known authorities, who show how the new tools are made and how they should be used. This section includes the use of coolants and gives much information not generally available.

It is our aim to offer general information regarding present practice in shops of various sizes, so that it will be of value both to the men who operate the machines and to those who are responsible for the results obtained. Other shop operations and problems will be considered in future volumes.

THE AUTHORS

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CHAPTER I

MODERN MACHINE-SHOP PRACTICE

A comprehensive survey of modern machine-shop practice becomes increasingly difficult because of the constant changes in machines, methods, and materials used, even on similar work. Instead of a few simple machines, each with a fairly well defined class of work to perform, we now have varieties and modifications that change with astonishing frequency. Where formerly the planer and shaper machines handled all flat-surface work, the milling machine, grinder, and more recently the broaching machine are now used almost exclusively on production work. In addition to new machines there are new methods, made possible by both new cutting tools and new materials. All these factors make it necessary for the men who are engaged in machine work, whether as owners, managers, or workers, to have a wider knowledge than ever before of the things which affect their industry.

With all the changes that have taken place, however, the principles of machine operation remain the same in most cases. If these principles are understood, it is much easier to change the practice to meet the changing demands. Having an understanding of these principles as a background, past experience should be of great value. However, if this past experience closes the mind against new methods, or prevents investigation as to their merit, it may easily become a handicap. More than ever before, the improved machines, methods, and materials now available make possible better products at lower cost. To secure their full value they require men of wider knowledge and broader vision in all executive positions, from general managers to foremen.

Since many of the elements of machining are embodied in the operation of the lathe, considerable space is devoted to this machine, which is one of the basic machine tools used in the shop. The drilling machine and the different methods of boring also receive considerable attention, while planing, milling, and grind-

ing, and other operations will receive attention in other volumes. The advances that have been made in the materials used for cutting tools make it necessary to devote considerable space to this subject, this space being divided between single-point tools, such as those used in turning and boring, and milling cutters or multiple-cutting tools. The introduction of these new cutting tools has added to the problems that confront the shop executive, especially in the small shop.

With the demand for large production at minimum cost there are few operations where the new tools are not likely to be economical. But their adoption may involve the purchase of new machines that will be not only faster but more rigid in the support of both tool and work. Then, too, the faster the machining operation, the more important the handling time, and jigs and fixtures may have to be redesigned to meet the new conditions. But greater cutting speed is not the only factor in favor of the newer cutting tools. Longer life between grinds is often of sufficient value to warrant their adoption. In some jobs, such as cutting the ring grooves in aluminum alloy pistons, the use of carbide tools obviates the necessity of changing tools during an entire day's run, some for even longer. The hardness of the material so reduces the wear that the groove width can be maintained over a long period. And there are cases where the turning tool itself is a diamond, to give the finish desired as well as to maintain size. These problems do not, as a rule, confront the management of the small shop.

While the small shop manager is usually limited as to the capital that can be invested in new machines and tools, he must know what equipment is necessary and economical if he must increase his output in some of his lines. He should know something of the methods of the big shops so that he can adopt, or adapt, some of their practices to advantage. His shop can probably work best with the various types of machines grouped in departments, as in the older shops. But there are likely to be times when by regrouping a few of his machines he can secure some of the economies of line production.

Selecting Machine Equipment.—Many factors must be borne in mind when selecting new machine equipment. Not only the kind of machine but the question of individual motor drive must be considered. From the viewpoint of first cost and power

consumption, the group drive has advantages. It requires less expenditure in motors and averages the power load to better advantage. But when machines are to be moved, either for realignment for a certain job or because of shop growth, the individual motor drive may be worth more than it costs. This is particularly true on special machines that are likely to be in demand for overtime work during certain seasons.

The problem of net cost is especially to be considered when selecting new equipment for the shop. The rate of production, probable total output needed, accuracy, kind of operators in the vicinity, and the amount of funds available must all be carefully considered. For continuous production the "time per piece" may be the main factor, although the probable cost for maintenance must also be considered. The rate of amortization, or how soon the machine will pay for itself, is another factor. This varies widely with both the kind of machine and the type of shop. In automobile work it is not uncommon to demand that a machine pay for itself in a year, and in some cases even in 90 days. This is due both to the very low labor cost already attained and to the frequent changes in product. In the average shop a machine that will pay for itself in three to five years is an excellent investment.

In other cases the factor of improved accuracy, because of both the better functioning of the product and the increased ease in assembling, may make a new machine profitable, with no increase in output. Floor space, the amount of time a new machine is likely to stand idle, its adaptability to more than one operation as well as its productivity must all be considered in figuring the net savings. These factors are vital in considering the purchase of special machines. While obsolete machinery is one of the greatest obstacles to economical production, there are cases where, under the existing conditions in the shop, it may pay to fix up an old machine for a special job and let it stand idle most of the time. The real manager must deal with net results, regardless of the size of the shop, as cut-and-dried theories do not fit all cases.

Methods and Men.—Modern machine-shop practice is constantly called upon to devise new methods which will meet new requirements, even in the handling of old operations. Some of the newer developments have almost eliminated certain types of

machines in production work. The miller, grinder, and broach are now almost universally used in producing flat surfaces in production work, although the planer and the shaper are still indispensable in the tool room and in the shop where work varies from day to day. In the same way the broaching machine is encroaching on the field which has been occupied by the miller for many years. The development of honing for automobile cylinders practically eliminated the cylinder-grinding machine from that field, but it still has its place in railroad shops and on special work.

The increasing demand for accuracy in the machining of many parts to secure the proper functioning of new apparatus has made necessary the devising and building of new instruments for measuring and inspecting the parts. Where a few years ago a thousandth of an inch was usually sufficiently accurate, we now use tenths of thousandths regularly and *indicate* to hundredths of thousandths in some cases in some inspection instruments.

Of course, it is not practicable to give full details of the operation of each machine in the different groups, nor is it necessary, as each machine builder issues instructions for the operation of his particular machine. Nor is it possible to show every machine in each group. The machines illustrated have been selected to give a general idea of what is available in the different lines and to show some of the work of which they are capable. From these illustrations the practical shop man can determine which type of machine will best handle the work he had in mind. Or, having one of the machines available, the examples shown will suggest methods of using the machine and give hints of tool set-up.

The section devoted to the machineability of metals and other materials should be especially useful to those whose experience has been confined to the more common iron and steels. While this is by no means complete, it contains information that will serve as a guide in machining other materials of a similar nature. If additional information is needed, the makers of the material in question should be consulted, as they are constantly experimenting as to the best method of handling their particular product. We recommend especially Brady's "Handbook of Materials" as a reference for many kinds of materials, as it

contains much of value to any shop man who wishes to be up to date.

Other sections take up the questions of estimating on work of various kinds, press work with its many problems and great possibilities of economical production, tool-room work, which includes the making of jigs and fixtures and heat treating, and other topics of practical value to the man who must get work out, accurately, rapidly and economically.

Summing up a somewhat condensed definition of modern machine-shop practice, we might say that it is the art and practice of selecting the proper machine equipment for the product to be made, with regard to the necessary accuracy, operation, and cost of production in view of the quantity to be made and the price at which it must be sold. This involves the operation of the equipment, the training of operatives, the purchase and follow-up of materials, the securing of maximum production while maintaining the good will and cooperation of the men, and many other problems that were unknown to the shop manager of fifty years ago.

In the same way the successful machinist—using the term machinist to apply to the man who can not only operate the various machine tools that are now in use, but who also understands why they operate and can detect trouble when they fail to function—must have a far wider knowledge than the machinist of the last century. He must understand far more about the principles behind the machines themselves and must have a wider knowledge of materials used as well as of the newer cutting tools. He must be familiar with more machines, many of them of the automatic or semi-automatic type, and he must be able to keep them in production as well as to tool them up for operatives who have almost no mechanical background. Competent men of this type have seldom received the recognition they deserve, either financially or otherwise.

Plant layout also affects the efficiency and management methods. And while few shops have a free hand in this respect owing to limitations imposed by the building itself, it is of interest to know how other shops are laid out. For this reason it has been thought best to include, in another volume of the library, a few plans of shop layouts for different operations. Some of

these are for shops larger than the average, as is the case in most automobile plants, but these contain suggestions that can be modified to suit some of the problems of the smaller shops. In the same way there will be shown high production methods that would be out of place in the average shop. But there are few shops that cannot find some suggestion adaptable to their own work.

CHAPTER II

THE LATHE

The lathe or turning machine is one of the fundamental machines in the machine-tool group. When equipped with a lead screw for screw cutting, as in the engine lathe, it is still for many kinds of general work the mainstay of the small shop. Primarily for turning work between centers or in a chuck, it is equally useful for boring with the work held in a chuck or on a faceplate, or even with the work bolted to the carriage and fed over a boring bar between centers. It is also used for drilling with the drill revolving in the live spindle or with the drill in the tailstock and the work revolved by the live spindle. Attachments are frequently made for milling small work and for backing off, or relieving taps and milling cutters. Given a good engine lathe and a supply of faceplates, angle plates, chucks, and tools, a good mechanic can handle a large variety of work.

In modern manufacturing, however, the lathe itself has become a turning machine, usually for roughing out work to be finished on other machines. Such lathes rarely cut a thread and the work is usually finished by grinding, both for the finished surface thus obtained and because grinding has been found to produce work more nearly round than can ordinarily be done by turning with a tool. Plain turning machines—turret lathes which are operated by hand, semi- or fully automatically—are now largely used on work that was formerly done on the engine lathe. Some of these lathes handle bar stock through the spindle while others hold castings or forgings in chucks. These are sometimes called chucking machines. Some of these perform all the operations of turning and boring automatically after the piece of work is fastened in the chuck. Chucking is usually done by hand, but the chuck is sometimes operated by air or by electric motor. Bar machines are frequently fully automatic as they feed the bar through the spindle after machining the piece and cutting it off. The operator merely supplies the bars to be machined.

Some types of lathes feed the blanks, which may be forgings, from magazines and through chutes or other mechanism that lead them to the chuck. In such cases the chucks open automatically to discharge the finished piece and grip the next one ready for work. Machines of this type are used only where the quantity produced is very large. They are frequently used on second-operation work.

Special lathes are also built for turning both ends of a piece at once, as in car axles and similar work. Sometimes the work is made from sheet metal formed and welded into shape, as with rear-axle housings for automobiles. In some of these cases the work is driven from the center and supported at each end near where the turning cuts are to be taken. Other special lathes are made for turning and grooving pistons, although in many cases these are machined on semi-automatic lathes of the Fay and similar types. Others prefer to use small, rigid machines of simpler construction, especially when the output is not so large. While labor cost is naturally lower on the more specialized machines, interest on the money invested in the machine, depreciation, and maintenance must also be considered. The quantity required frequently determines the type of machine selected.

The engine lathe is probably the most versatile of all the machine tools and, in the small shop, it will be used for many jobs that in the larger shop would go to the turret lathe, the boring mill, or the horizontal boring machine. But if the regular run of work requires a dozen or more duplicate parts to be made with fair frequency, the turret lathe can now be considered, as standard tools are now made to handle a wide variety of work and to be so easily set up that small lots can be made economically and have the advantage of being commercially duplicates. Vertical boring mills with side heads can also be used in a similar manner. Where the pieces are heavy, some consider it easier to chuck them on the horizontal table of the boring mill rather than in the lathe. Experience of the men, equipment available, and personal preference all play their part in making either method seem most desirable. In any case, careful attention should be given to both chucking and tooling, as both seriously affect costs. Holding devices and tools must insure sufficient accuracy for the work in hand, but beyond this point there is

room for careful study as to how much can be economically spent to save a few seconds of either chucking or machining time. If the piece is made but seldom, both chucking and tool costs should be kept as low as possible. If, on the other hand, the pieces are needed in large lots, much more can be economically spent on both fixtures and tools.

Lathe Work between Centers.—When lathe work is to be turned between centers, it is important that the centers in the end of the shaft, or whatever the piece may be, are properly drilled and countersunk, or reamed. The size of the center depends on the size of the piece and on work to be done. Table I shows sizes that are considered advisable by a well-known maker of center drills. These can be varied to some extent as occasion demands. Where heavy cuts are to be taken, the centers should be larger than where only a finishing cut is necessary. If the surface is to be rolled or burnished by a roller in the tool post, as in the case of axles in railroad shops, the center should be as large as seems advisable, on account of the heavy side pressure exerted by the rolls.

Table I.—Sizes of Lathe Centers in Work to Be Turned

Diameter of work, in.	Diameter of center drill, in.	Diameter of countersink, in.
3/16	3/64	3/32
1/4	1/16	7/64
5/16 to 1/2	1/16	1/8
9/16 to 3/4	5/64	9/64
13/16 to 1	5/64	3/16
1 1/16 to 1 1/4	3/32	7/32
1 5/16 to 1 1/2	3/32	1/4
1 9/16 to 1 3/4	3/32 to 1/8	9/32
1 13/16 to 2	1/8	5/16
2 1/16 to 2 1/2	5/32	3/8
2 5/8 to 3	3/16	7/16

The angle of the center is also important. The usual angle in use today is 60 deg., although there may still be a few old railroad lathes with their 77-deg. angle still in use. There have also been cases where the 90-deg. angle was used. The fit of the center is most important at the tailstock or dead-center end, where the work revolves on the stationary center. The dead

center should be lubricated, which is not always easy, to avoid scoring and wearing the point on one side. Ball-bearing centers, in which the center turns with the work, have many advantages on heavy work. They should, however, be so designed that the

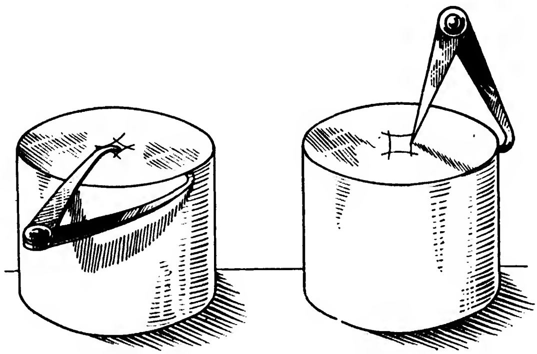


Fig. 1. Fig. 2.
Figs. 1 and 2.—Methods of finding center of bar.

overhang is limited so as to avoid undue springing under the stress of the cutting tool.

In any kind of shop, work must be centered before turning between centers, and some of the methods shown in Figs. 1 and 2 will be found useful. If there are many pieces to be done, it may pay to make up the rig shown in Fig. 4, but for single pieces the caliper or center-square method is very convenient. By chalking the end of the bar and scribing it with calipers or dividers as in Fig. 1, it is easy to locate the center, which can then be prick-punched and drilled. The same is true of the center square in Fig. 3. But the easily made device in Fig. 4 is more convenient, especially if there is an old hand or speed lathe available that can be left just for centering work of this kind. The two studs *S* support the cross bar *P* in line with the center of the lathe spindle. The outer end of the cross bar has a cone cut in the end to receive the ends of bars to be centered. The back side of this central part of the cross bar is recessed to permit the drill chuck with its center reamer to reach the end of the bar as it is fed in by the tail center or by other means.

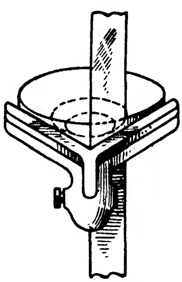


Fig. 3.—Using the center square.

Springs on the studs help to support the rod being drilled and return the cross bar when the rod is withdrawn. A coned cup in the tail center makes it easy to support the rod centrally while being drilled. Although intended primarily for round rods, the cups will center hexagon, octagon, or square rods with satisfactory accuracy.

For work that is held in a chuck the use of a pointed tool in the cross slide of the lathe (Fig. 5) makes an easy way of finding the center. After locating the center, it is drilled and reamed

Fig. 4.

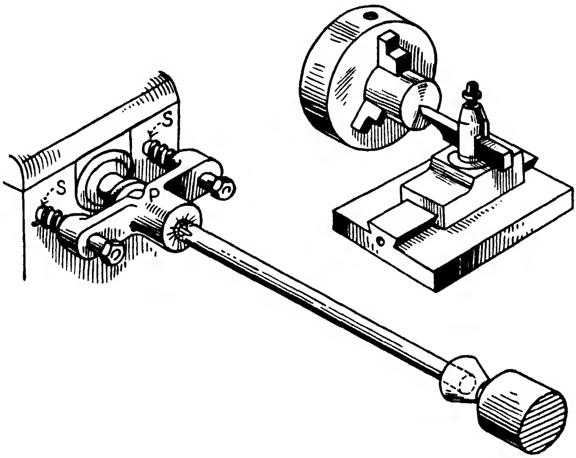


Fig. 5.

Fig. 4.—An easily made center drill.
Fig. 5.—Centering with a special lathe tool.

with a center reamer held in a chuck in the tail spindle. In all centering work it is important that the ends of the work be square, as this has a direct effect on the accuracy of the work turned.

Good and Bad Centers.—The effect of not having the ends square and also other common defects in centering are shown in Figs. 6 to 11. A good center is necessary to provide a good bearing for the lathe center, which takes the thrust of the cutting tool while the bar is being turned. With standard center reamers the main thing to watch is that it does not cut deep enough to leave a shoulder as is shown in Figs. 7 and 8. The effect of the wrong angle on the bearing can be readily seen in Figs. 9 and 10, while Fig. 11 shows an exaggerated case of the end not being squared and the varying bearing on the center. For shops not

provided with center reamers, Table I gives good proportions for the diameter of drill to use and the large diameter of the coned reamer, which should be 60 deg., this being the standard center angle.

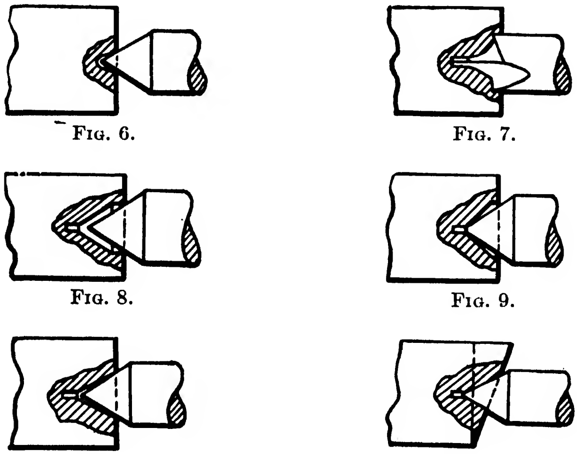


FIG. 6. FIG. 7.

FIG. 8. FIG. 9.

FIG. 10. FIG. 11.

FIGS. 6–11.—Six faulty centers.

In most job shops it is found advisable to have two sets of centers for each lathe. One is kept for roughing work and the other for work that must be accurate. In these days of lathe center grinders, all centers are hardened and should be ground

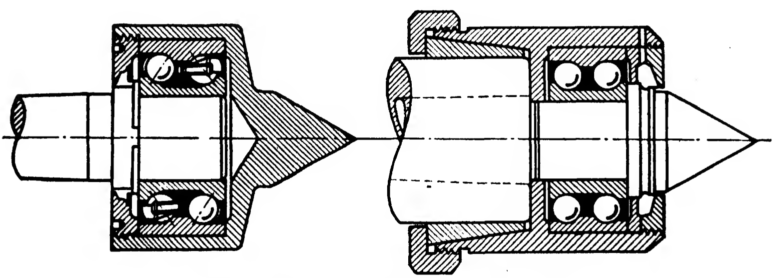


FIG. 12.—Two types of ball-bearing centers.

to the correct angle. In addition to the regular solid centers there are many cases where a ball-bearing center is a great convenience, especially on heavy work. These are now obtainable from regular makers, two being shown in Fig. 12. They

prevent wear on the point of the center itself and tend to increase the accuracy of the work. They also eliminate the necessity of lubricating the lathe center, which is not always easy or satisfactory. On heavy turning such as forged rolls, it was formerly necessary to use white lead and similar heavy lubricants on the centers while turning. For turning hollow work, such as pipe, large coned centers, as shown in Fig. 13, are convenient. These can revolve either on a plain bearing as shown, or have a ball bearing, which is better.

Special centers are frequently made to accommodate work that is out of the ordinary. A live center may be square of some special shape to fit an opening in the end of the work; or the tail

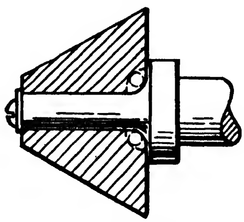


FIG. 13.

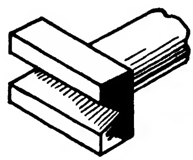


FIG. 14.

FIG. 13.—Center for pipe or hollow work.
FIG. 14.—Cross-V, or drilling center.

center may have a very accurate hole to receive the end of a slender piece of work and support it near the point at which it is to be turned. When the lathe is used for drilling, as is often the case, it is customary to make tail centers that will hold the work being drilled. A center with a V across the end is seen in Fig. 14 and is very convenient for drilling holes crosswise in a round bar or pipe. Modifications of this can be made for a variety of work.

Turning Slender Work.—Slender work must be well supported while turning to prevent springing and catching on the tool. It also requires a lathe in good condition, as to both the fit of the spindle in its bearings and the carriage on the ways. Sometimes a hollow mill is used on long, slender work, the cutting points supporting the work from several points.

A method of turning slender work in the lathe is shown in Fig. 15. The steel rods were turned to a diameter of 0.1 in. with a tolerance of ± 0.001 in., and 4 in. long. The rod was held

in a split chuck or collet. A drill chuck was put in the tailstock, with a bronze bushing 3/8 in. outside and 0.102 in. in the hole. With the rod projecting but a short distance for the collet the end was turned to 0.101 for about 5/8 in. The collet was loosened and the rod pulled out about 2 in., the turned end being pushed

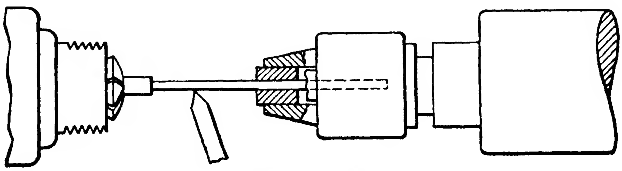


FIG. 15.—Turning slender work.

into the bushing in the tailstock. The bushing acted as a support for the rod as it was turned. Two-inch lengths could be turned without difficulty. With a hole in the drill-chuck shank, fairly long pieces could be turned in this way.

The most common method of driving centered work in a lathe is with a single-tailed dog, as in Fig. 16. The illustration also shows what happens when the tail of the dog strikes the bottom of the slot in the faceplate before the work is fully in place on the center. This is a point that should be carefully noted in putting a piece of work in the lathe. The work should always be accurately centered on the points of the lathe centers and not be crowded to one side as shown, as accurate work is impossible under these conditions. Danger of cramping in this way can be avoided by using a straight-tailed dog. This, however, necessitates a driving stud in the faceplate. There are also double-tailed dogs with both straight and bent tails. Some prefer a double-tail straight dog and in some cases use a faceplate with the driving studs in an auxiliary plate so as to be adjusted to insure equal driving of the two tails. Such a faceplate is seen in Fig. 17 which shows how the studs can be moved on the main faceplate to insure equal bearing against each tail of the dog. A simple

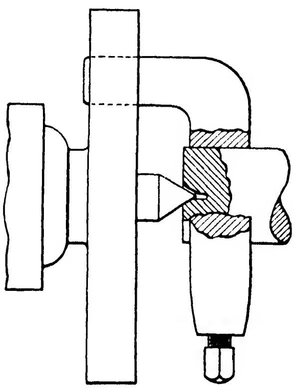


FIG. 16.—Work crowded off center by lathe dog.

driving clamp dog, made of two pieces of flat steel bent to shape, and held with two bolts, is shown in Fig. 18.

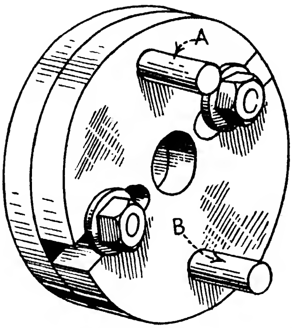


FIG. 17.—Faceplate for driving double straight-tailed dog, evenly.

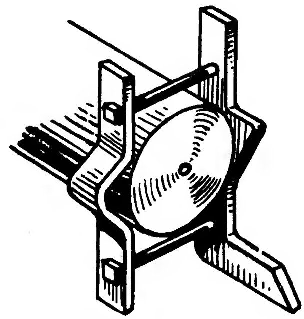


FIG. 18.—Simple form of clamp dog.

Keeping Lathe Centers in Line.—Unless the two lathe centers are in line with the ways of the lathe, it will be impossible to turn a bar that is the same diameter at each end. Figure 19 shows a device to align lathe centers so as to turn work parallel. It consists of two bushings deeply countersunk to fit the lathe

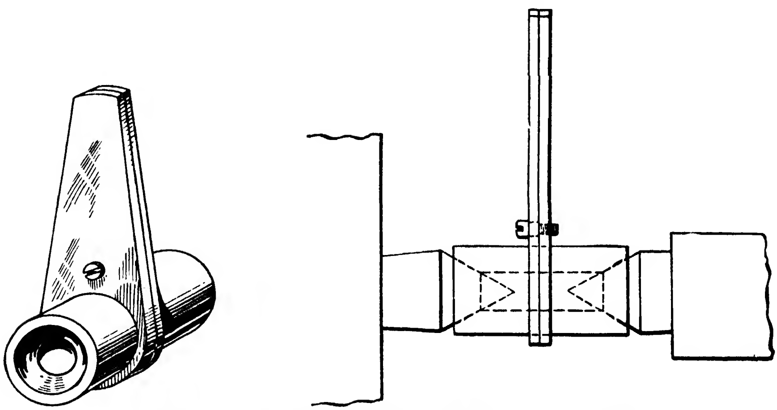


FIG. 19.—Device for checking alignment of centers.

centers and two pieces of flat steel. The bushings are shouldered and are forced into holes in the pieces of flat steel. A shoulder screw, placed as near as possible to the bushings for leverage, acts as a pivot. With a mandrel through the bushings to bring them into alignment, a line is scribed on the ends of the pieces of steel.

In operation, the device is placed between the centers with the pieces of flat steel in a vertical position. Any horizontal misalignment of the centers will cause the bushings to move out of line and the pieces of steel to swing upon the pivot screw, bringing the halves of the scribed line on each piece of steel out of register. To align the centers, it is necessary only to adjust the tailstock center until the halves of the scribed line coincide.

Faceplate Work.—Faceplate work is work which does not depend on the two lathe centers for location and accuracy but is, in some way, fastened to the faceplate. Such work may vary from turning and facing the end on a heavy pipe fitting to locating and boring holes in jig or fixture plate, where the holes must be extremely accurate as to both diameter and distance between centers. The former requires only moderate accuracy but care-

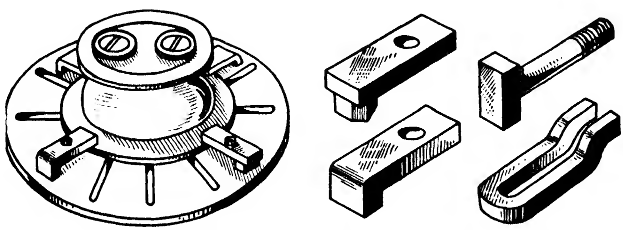


FIG. 20.—Example of faceplate work.

ful attention as to clamping, while in the latter case both accuracy and clamping that will avoid all spring of the parts are necessary.

An approach to the jig and fixture problems is shown in Fig. 20 where two holes must be bored in one end of a fairly heavy casting. This shows the casting centered on the faceplate for turning and facing the end. Bent clamps are convenient for this work as shown, but a straight clamp can be used and the outer end blocked up, as shown at the right. A hairpin clamp and a T bolt are also shown, as these both have a place in work of this kind. In some cases it is more convenient to locate the work with the faceplate on a bench, rough location being secured by measuring from the edge of the faceplate to the flange on the work. In fact, this method of locating is probably sufficiently accurate for the work shown. This method assumes that suitable arrangements exist for lifting the faceplate and the work from the bench and holding it while the faceplate is put on the lathe spindle nose.

Whether the work is put in place on the bench or with the faceplate on the lathe, means must be provided for holding the work during the chucking operation.

After the flange of the casting has been bored and faced, there are two holes to be bored and faced as shown, a given distance apart. To locate these, it is common practice to force a small stick across the opening of each hole, as shown, for use in centering the holes to be bored. Frequently a piece of sheet tin is tacked on the sticks in the center, for convenience in scribing the center itself. Sometimes, however, a piece of hardwood is all that is necessary. If several pieces of the same kind are to be machined, the sheet tin is used and the center prick punched in it after the first hole has been located. With the stick in place it is easy to locate the center with calipers from the outside of the projection, using the methods for centering round bars, as described on page 12. If it is necessary to have the center distance between the holes fairly accurate and if the casting is not perfect in this respect, it may be necessary to compromise by shifting the hole at each of the two openings a little, as measured from the outside of these openings in the castings. With both cross sticks in place, the first step is to find the center of each hole from the outside, marking the center on the sticks. Then measure the distance between the center holes on the sticks. If not correct according to the drawings, they can then be shifted to the best compromise possible.

With the center of each hole located, the whole casting must be shifted on the faceplate until one of the center marks comes in line with the lathe center; then the casting is clamped in that position. After boring and facing, the casting must be again shifted to the other center and the second hole bored and faced. When the work is heavy, as in this case, many prefer to use a vertical boring mill instead of a lathe, if one is available. But the work can be done on the lathe, even if not quite so conveniently, and the lathe can handle a wide variety of work that could not be done on the boring mill. The methods used in locating holes accurately with relation to each other will be described under the heading of Tool-room Work in another volume.

Angle-plate Work.—Many kinds of work can be handled by the use of angle plates that would be very hard to chuck or hold in any other way. Two examples of work of this kind are shown

in Figs. 21 and 22. These angle plates are made at the proper angle to suit the work to be done, as shown in Fig. 22, but the standard angle plate has the two sides at 90 deg., as shown in Fig. 21. This form of angle plate will handle a large variety of work in addition to the type shown. If, for example, it is desired to bore a hole in the end of a steel block, the block can be

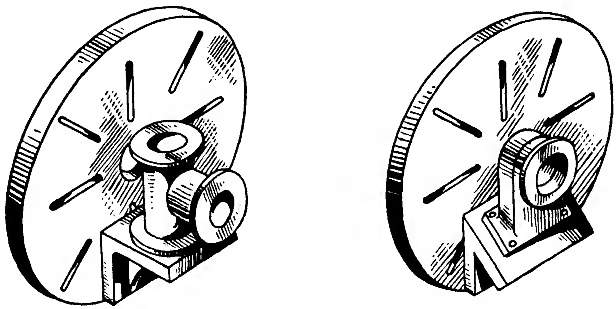


FIG. 21. FIG. 22.

FIGS. 21 and 22.—Two angle-plate jobs.

readily clamped flat on the angle plate, the end centered, and the hole drilled and bored without difficulty, as in Fig. 38.

There are also times when it is necessary to bore or otherwise machine the end of a shaft while the other end is located on the live or spindle center and supported in a steady nest, as in Fig. 45. Such operations require the use of a steady rest

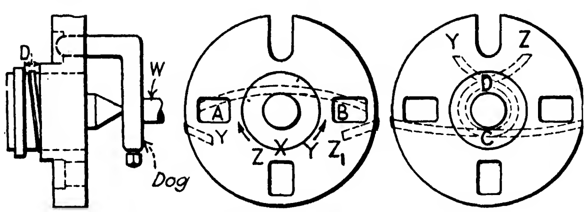


FIG. 23.—Holding work against lathe center.

for the outer end of the shaft and a method of holding the other end in contact with the live center. This method of holding is usually called bridling and the device for holding is called the bridle. For light work the work is frequently held back by binding the dog to the faceplate with a strap of some kind. In the days when belts were more commonly used and laced with leather, the belt lacings were used for bridles and held

the work securely against the live center. Such a method is shown in Fig. 23. A more elaborate method is the strap shown in Fig. 24; somewhat similar collars, made of metal and held against the faceplates by bolts, are also used.

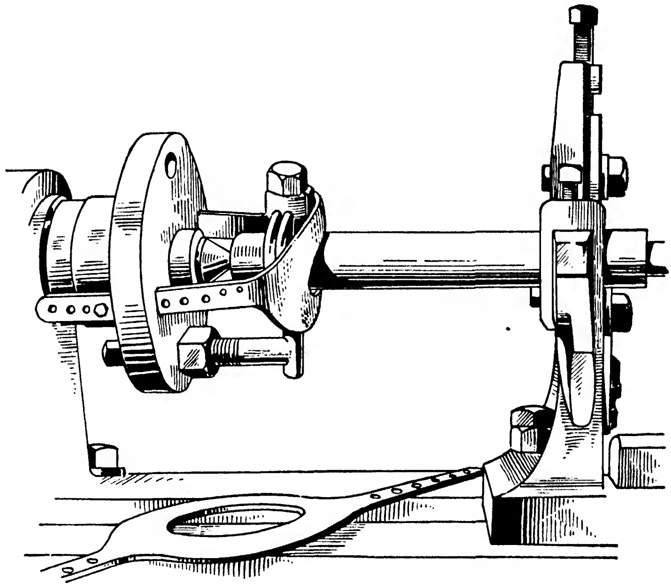


FIG. 24.—Another form of leather bridle.

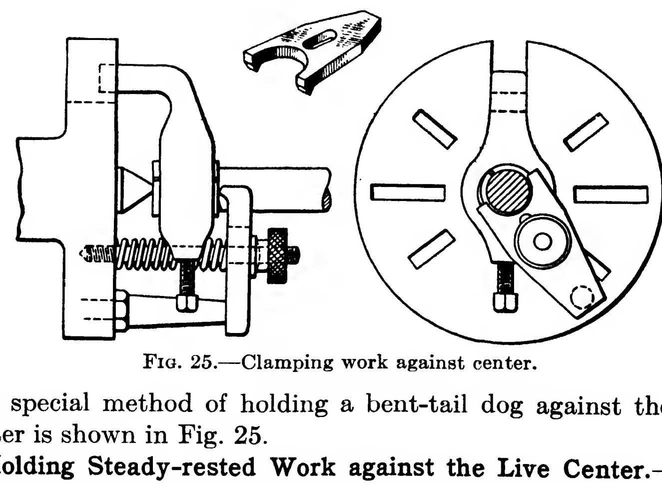


FIG. 25.—Clamping work against center.

A special method of holding a bent-tail dog against the live center is shown in Fig. 25.

Holding Steady-rested Work against the Live Center.—The work is driven by an ordinary dog in the usual manner, but to

prevent its being marred by the dog screw, a split bushing of brass is used. The work is held against the live center by a steel clamp, in one end of which is milled a semicircular opening of the same radius as that of the work, and having sharpened toes. Clamping takes place on the front face of the brass bushing. Since the sharpened toes of the clamp impinge across the diameter of the bushing, and the throat of the semicircular opening is pushed against the work, there is no danger of distortion. This is shown in Fig. 25.

A knurled nut in conjunction with a washer, having a spherical face, gives ample clamping pressure. A slot in the clamp insures quick release of the work when the clamping nut is loosened a turn or two. It is, of course, necessary to have clamps and bushings for each diameter of work. Some keep one lathe for this class of work and it is a simple matter to change the clamps and the bushings for the different diameters.

CHAPTER III

CHUCKS AND CHUCKING

Chucks may be divided into two general classes, those for use on a large variety of work and those designed for special purposes. Opinions differ as to the advisability of selecting two-, three-, or four-jawed chucks and as to whether they should have universal or independent jaws. Selection should depend on the kind of work that predominates in the shop.

For round-bar work where great accuracy is not required, the three- or four-jawed universal chucks are very convenient. They

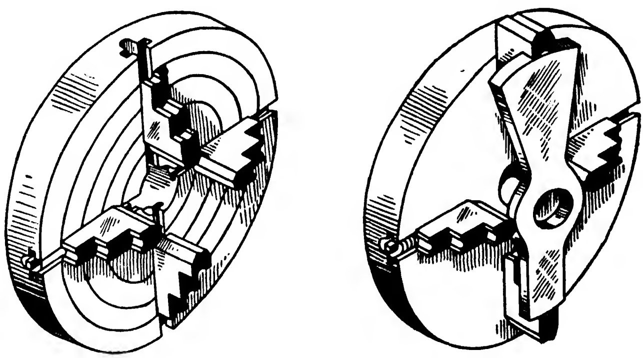


FIG. 26.—Stepped jaws for lathe chucks.

are self-centering and as accurate as can be expected, especially when we consider the way in which they are frequently abused. For work that is not round, which includes the average work that comes into the average shop, the four-jawed chuck, preferably with independent jaws, has many advantages. When provided with stepped jaws, as in Fig. 26, a great variety of work can be held in them, especially when one or more of the jaws are turned, as shown. Here the jaws at the ends of the piece locate and support the under side of the work, as well as hold it on the ends. The other jaws hold it on the sides. Many other combinations are possible to hold a large variety of work.

Separate jaws are also used on faceplates for holding odd-shaped work, and occasionally extensions are put on the faceplate at any desired point for holding oversized work. One such method is shown in Fig. 27, where four angle pieces form

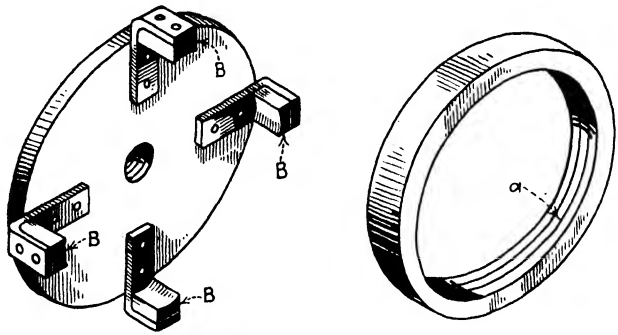


FIG. 27.—Temporary jaws on faceplate.

fixed jaws and are lined with wooden blocks that are bored out to the right size to hold the work. Such blocks are, of course, used only for holding work already finished on the outside, and for light cuts on the inside and face. The work is forced into place and held by the friction of the blocks on the work.

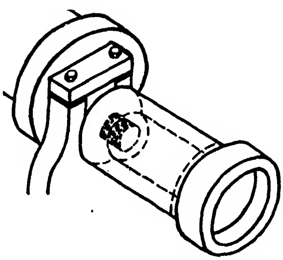


FIG. 28.—A simple form of pot chuck.

There are also many types of special chucks. One type generally known as pot chuck includes almost any form that surrounds the work, as shown in Fig. 28. This is screwed on the spindle nose and is bored to suit the work to be held. More elaborate forms of special chucks are used in a wide variety of work, a few of which are shown.

Special Chucks.—Two methods of chucking work in the lathe are shown in Figs. 29 and 30. The first is the spider of an airplane-propeller hub which is located by special chuck jaws and held back against the face of the chuck by straps as *A*. One important dimension on this job is the length of the hub from the faceplate to the end. So the block *B* is fastened to the chuck face and the facing tool set by using a standard block, or distance

piece, between the tool and the face of this block *B*. This insures the length of the hub being correct when the tool is fed across the end.

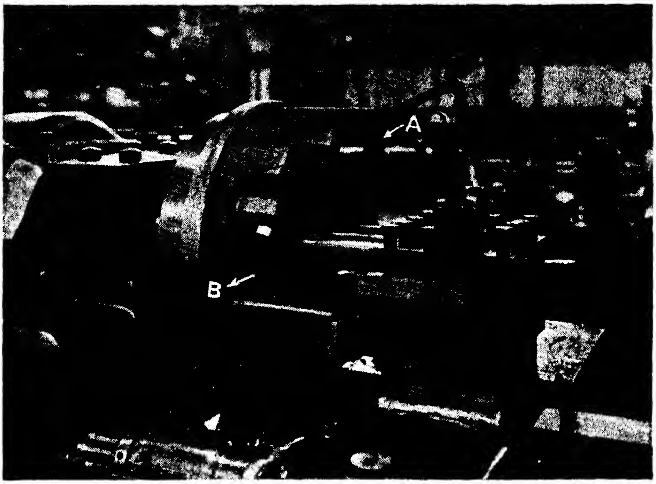


Fig. 29.—Using space blocks in facing.

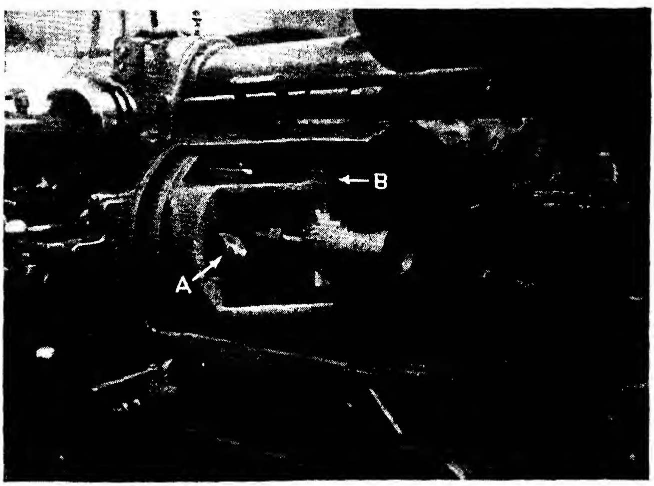


Fig. 30.—Chuck for two- or three-bladed hub.

The other chuck will carry either a two-bladed hub, as shown, or a three-bladed hub by using the point *A* to locate one of

the projecting ends. The hub is centered by a bolt at B which acts as a pivot for indexing it from one barrel to the other. The hood, or chip guard, is shown open at the front side for putting the work in place.

FIG. 31.—Special chuck for holding propeller blades.

Another example of holding work for boring in the lathe is seen in Fig. 31. This is the hub of a controllable propeller blade which is held in a long fixture bolted to the lathe bed in front of the headstock. The blade to be bored is clamped in a central portion which revolves in the main housing of the fixture, the outer end being supported by the ring A. The inner portion carrying the work is driven by the lathe spindle. The tools are held in the bridge fixture that is bolted to the lathe carriage. The hole is first bored by step drills, and then a taper reamer is used to finish. The taper-plug gage is used for gaging the depth of the hole, the dial gage making contact with the end of the hub. The axial tolerance on this job is ± 0.001 in. The work, which is an aluminum alloy, runs at 325 r.p.m.

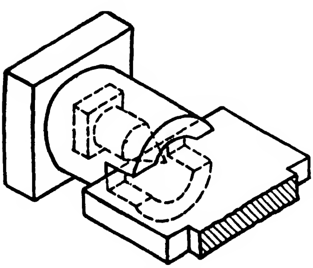


FIG. 32.—Chuck for driving flat pieces.

A somewhat unusual form of chuck is seen in Fig. 32. This is for turning special flat cutters used in some types of brass work in turret lathes. The chuck is bored and threaded to go on the

lathe spindle nose and has a square on the end for a wrench. A slot across the center of the end allows the back end of the flat cutter to locate itself on the live lathe center with both sides of the cutter in the slot across the end. With the other end of the cutter located on the dead center, this type of chuck drives the cutter while it is being turned to size and is entirely out of the way of the tools.

Holding Thin Work in the Lathe Chuck.—Thin plates are difficult to hold in a lathe chuck without springing them. It is not easy to get them square with the lathe spindle. When a chuck wears, the jaws spring out when they are locked on a piece of work and add to the trouble. A method of overcoming this difficulty and of holding thin pieces in the chuck is shown herewith.

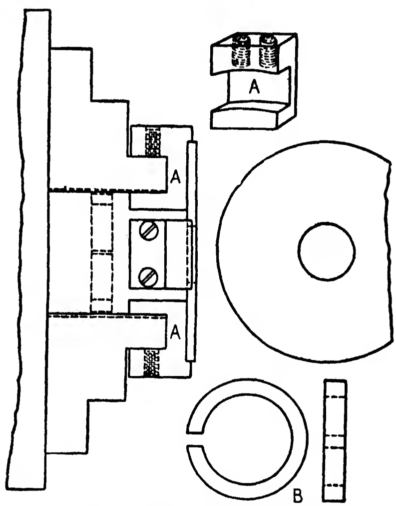


Fig. 33.—Chuck for thin work.

False jaws, as shown at *A*, Fig. 33, fit over the regular chuck jaws and are held by headless set screws. The outer side of the false jaws are bored out to the size of the piece to be held. In order to take the slack out of the jaws and the jaw screws, the spring *B* is made of the right size to allow the jaws to close and yet take the spring out of them as they clamp the work. The jaws should be clamped on the spring collar before boring the jaws for the work.

With the jaws bored to fit the work, thin pieces can be held very satisfactorily. This method was used in facing phosphor bronze range-finder dials from 4 to 15 in. in diameter and from $\frac{3}{16}$ to $\frac{1}{2}$ in. in thickness. Separate spring collars had to be made for each size and it is better to have the false jaws, too, fit the work.

Care of Chucks and Faceplates.—Care in using and storing both chucks and faceplates is necessary if good results are to be expected. The threads that fit the lathe spindle nose should

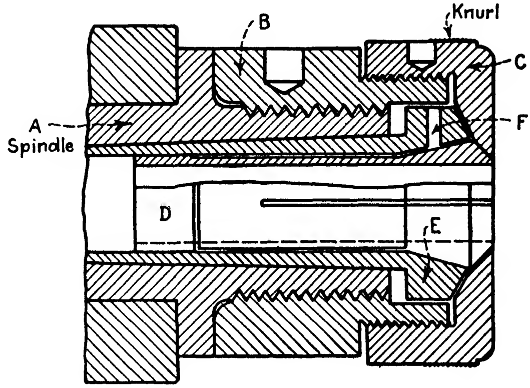
be kept free from dirt and chips. Accuracy of the chuck should not depend on the fit of the thread but rather on some plain surfaces. Thread fits are very difficult where accuracy is desired if the parts are to be taken apart and again put together, as with lathe chucks and spindle noses. It is for this reason that so-called "screw chucks" are not used to a greater extent. Where great accuracy is required, chucks in which the work screws into the chuck itself are used only once. The chuck is screwed on the spindle nose, the thread for the work is chased in the chuck, and the chuck is never removed until the job is done. Then the chuck is thrown away.

It is for this reason that the practice of using chucks from one machine on other machines is not followed, if accurate work is required, as in second-operation work, where the surface to be held has been machined previously. There is, of course, a large variety of work in which no such precautions are necessary. But even on work that is not very accurate it pays to keep the threads clean and to check the truth of the jaws occasionally.

For the same reason faceplates should receive more care than is usually the case. They should not be hammered or dented, and it is well to take a very light cut over them occasionally if nice work is to be done. A straightedge across the faceplate should show it a trifle low in the center. This is done to make it easy to clamp work firmly against the faceplate, which would be more difficult if the plate were high in the center.

For holding round work, such as bar stock—especially if it is a second operation—a collet, or contracting chuck, has many advantages. These were designed originally for watchmakers and small-screw machines, but they have been found so useful that they are now common on engine lathes and other machines. A typical collet is shown in Fig. 34 where *A* represents the lathe spindle, which in this case carried a center about 1⅛ in. diameter at the small end. To this center is fitted the hardened and ground taper sleeve *E*. This sleeve was ground to fit the collets used on other lathes. As this rig admits of much larger size collets than the ordinary draw-in collet lathe, some extra sizes can be made. The machinery steel sleeve *B* was next fitted to the spindle, and by means of a spanner wrench screwed up tight to the shoulder. This sleeve has a fine thread on front end to which a cap *C* was fitted having a taper to match the

front end of the collet. The working of this rig must be apparent at sight. Both tapers of the collet being used, and as the cap *C* is made with a fine thread (20 per inch), a very powerful grip is obtained. A spanner wrench is fitted to the cap *C* also. Several have used this chuck quite extensively in their shops, where it is usually preferred to the ordinary draw-in collet. It is nearly as rapid in manipulation, very stiff, and rigid.



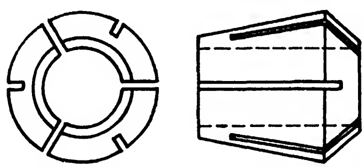


FIG. 34.—Collet chuck on lathe spindle nose.

Where the use of long bars is not required, an ordinary small center lathe with no hollow spindle can be used by extending the sleeve *B* and fitting it to a short collet as shown below. The sleeves *B* and *C* should be made of machinery steel, case-hardened; a pin *F* forms a key to prevent the collet *D* from turning.

Turning Large Curved Surfaces.—In machining link blocks to fit the links of locomotives, unless some special facilities for machining the curved surfaces are at hand, the fitting is somewhat of a job, as the radius of curvature is such as would require the use of a lathe or a boring mill of great swing. However, the illustrations show a method by which the curved surfaces are

machined in a lathe of comparatively small swing in the shops of the Central of Georgia Railway, Macon, Georgia.

Referring to Fig. 35, *A* is a faceplate screwed on the spindle of the lathe and fitted with the crankpin *B*. A plate *C*, slotted to fit the crankpin, is held against the faceplate by a nut and a large washer. The rod *D*, attached to plate *C*, is fulcrumed on the stationary rod *E* at a distance from the lathe center equal to the radius center of the link block. It will readily be seen that with the lathe in motion, the crankpin must impart vertical motion to the plate *C*, which is prevented from free horizontal movement by the fulcrumed rod attached to it. Thus the

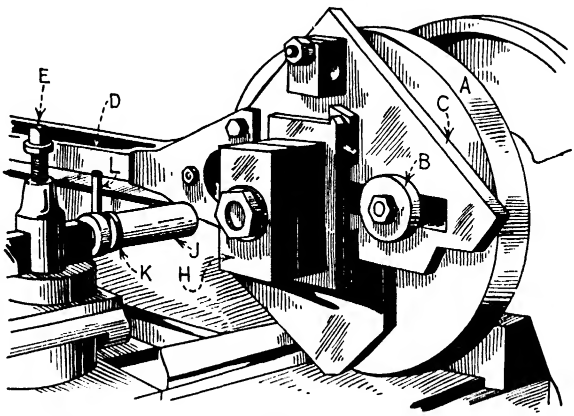


FIG. 35.—Tool for making concave surface on block.

resultant motion must be an oscillating one in the path of an arc, the radius length of which is governed by the position of the fulcrum.

The link block *H* is mounted on a fixture attached to the plate *C*, the fixture being bridged over the slot to permit the nut and the washer on the crankpin to pass under it. The tool bit, held in the sleeve *J*, is so mounted as to permit it to clear the work on the back stroke. A cam-shaped slot at *K* and the pin *L* cause the sleeve to move slightly to the right as the tool bit lifts, thus permitting the tool bit to clear the work both vertically and horizontally. The pin *L*, in addition to its function as a cam pin, acts as a stop, bearing against the end of the slot when the tool is cutting. A spring returns the tool bit to cutting position upon the completion of the back stroke.

In Fig. 35 the tool is set for machining the inner or concave surface of the block. For machining the outer or convex surface, the sleeve is turned half a revolution and the tool bit is reversed, the cam-shaped slot being long enough to permit this adjustment.

The method of setting up the device is shown in Fig. 36. One end of the stationary rod *E* is attached to the protruding end of the front bearing of the spindle, while the other end rests in a notch in the block *M*, which stands on a bench nearby. The fulcrum pin *N* can be secured at any position on the rod to suit the radius of the link block to be machined. Graduations on the rod facilitate setting the fulcrum pin to any radius length desired.

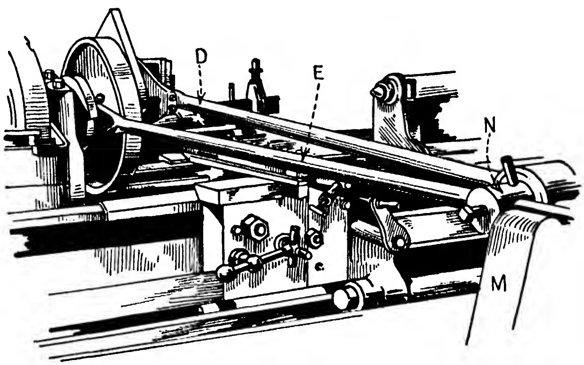


Fig. 36.—How the device is set up.

Turning by Templet.—Turning by templet has been done for years, by the use of either a thin metal templet from which the lathe man guides his cutting tool, or the heavy, perhaps hardened, templet used to guide the cross slide of the lathe carriage by means of a roller or other contact. In such cases the cross-feed screw is removed or disconnected so that the tool can move freely to and from the lathe center as it is fed along the bed. Contact between roller and templet is usually maintained by means of a weight with a cable over a pulley.

The latest development of this kind is the electric control unit such as developed by the Keller Engineering Company for use in its die-sinking machines. Here electrical contact controls the feed screw through a motor and suitable gearing and reproduces any desired contour within a guaranteed accuracy of

0.001 in. This means that it also reproduces errors in the templet to the same accuracy which necessitates the most careful preparation of the templet to be used. The illustration (Fig. 37) shows a special form turned on a Monarch lathe equipped with the Keller control.

Boring and Boring Tools.—Boring in the lathe is the reverse of turning. With the work held in a chuck or on an angle plate, the boring is done with a tool having its cutting point turned at right angles from the shank, and fed into the work with the carriage. Unless the work already has a hole in it, the first

Fig. 37.—Typical example of form turning with Keller control.

move is to drill an opening large enough to admit the boring tool. Boring operations have already been shown in Figs. 20, 21, 22, and 26. These operations are performed with the regular boring tools, either with the cutting point bent at an angle to the forged shank, or with boring tools fitted in special holders. Both of these will be shown later.

In Fig. 38 is shown a boring tool or bar, held in a heavy holder in the tool carriage of the lathe, boring a half hole in each of two blocks that are held on an angle plate. Another method of boring in the lathe is shown in Fig. 39. Here the work is clamped to the cross member of the lathe carriage after the cross slide has been removed, and the boring bar is held between the lathe centers. The bar can carry one or more cutters. It must be

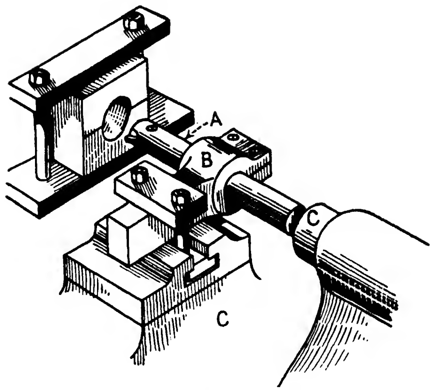


FIG. 38.—Boring tool in tool post.

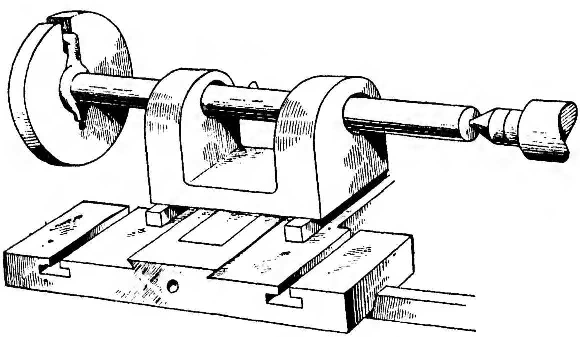


FIG. 39.—Boring bar between centers.

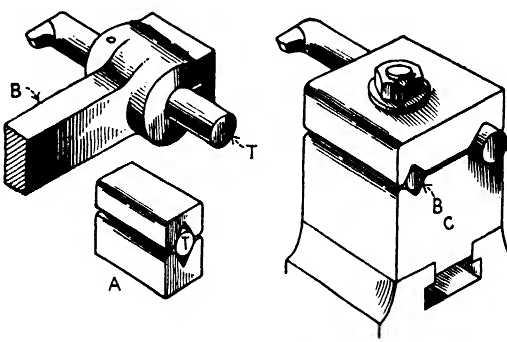


FIG. 40.—Two types of boring-tool holders.

small enough to go through the cored hole in the casting but should be as large as possible, for stiffness. With the boring bar driven by the lathe spindle, the carriage is fed along in the usual way, feeding the work over the bar, which cuts as it turns and feeds.

Three types of boring-tool holders are seen in Fig. 40. At *A* are two V-blocks for clamping round-shank boring tools in the slot of the conventional tool post. At *B* is a holder with a shank that also fits into a tool post. The block holder at *C* replaces the tool post and is bolted rigidly to the tool block itself. It is shown with two different sizes of V's for holding tools with large and small shanks.

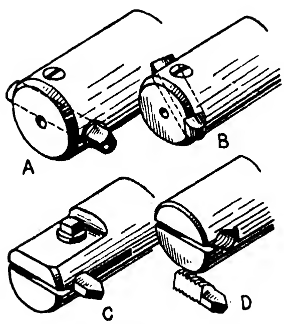


Fig. 41.—Holding cutters in boring bars.

Four methods of holding the cutting tools in the ends of boring bars are shown in Fig. 41. In *A* and *B* the cutters, or bits, are held in their slots or holes, by set screws on top. The object in setting the cutter *B* at an angle is to have it reach into a corner for a hole that does not go through the work. Cutters *C* and *D* are for grooving or threading, both being clamped in a split bar. The tool and its hole are threaded in *D*, to permit accurate resetting when removed for grinding. The thread on the cutter need be little more than a single cut with a thread tool, as it needs only depth enough for the threads in the bar to locate in inserting the cutter. By flattening both sides of the cutter and removing the thread from the sides of the hole in the bar, the cutter need not be screwed in but can be turned at right angles, pushed in place, and turned back into position.

For accurate drilling in work of this kind, many use the type of drill shown in Fig. 42 and known as the cannon drill. This drill can be held rigidly in such a tool block as *C*, Fig. 40, and will cut a very true hole. Drills like this can be easily made from drill rod. They should be ground off to half the diameter on the end, and given the proper clearance. For use on brass the ends do not need to be ground parallel with the center as at *A*, but can be sloped off as at *B*. They can also be used as reamers for short holes.

Proper clearance is important in boring tools, the angles necessary depending on the diameter of the hole being bored.

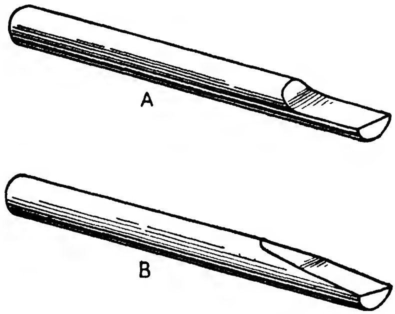


FIG. 42.—Cannon drills.

The effect of this can be seen in Fig. 43, which shows four different diameters with tool outlines in place. Boring tools should be set at the center for ordinary boring work. Figure 44 shows two boring tools in a cut to indicate the effect of the cutting angle. At *A* the cutting edge is at an angle which makes a tendency for the tool to spring away from the cut. At *B* the forward edge is square with the cut and avoids this tendency. If, however, the cutting angle slopes the other way it creates a tendency to dig into the work and cut deeper than was intended.

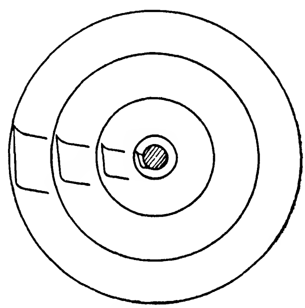


FIG. 43.—Setting boring tools in work.

Spring of the tool is always to be watched in boring tools, espe-

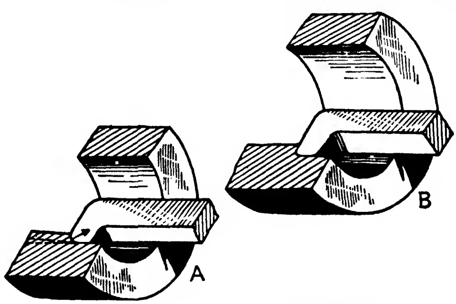


FIG. 44.—Effect of cutting angle.

cially where they must be small to get into the hole, and have considerable overhang.

Steady and Follow Rests.—Steady rests have already been mentioned in connection with the work shown in Figs. 45 and 46. They are three-jawed stationary supports for use either at the end of work, as already shown, or in the center of long shafts that might otherwise spring under the cut. In some cases two or more steady rests are used in this manner. Follow rests are used for a similar purpose when turning or threading long work of small diameter. As the name indicates, the follow rest follows the tool, supporting the work directly behind the cut, or as near to it as possible. In turning work it is customary to have the follow rest bear on the diameter that has just been turned. This is necessary on the first cut but is optional on finishing cuts. The follow rest should obviously bear on the diameter which it is desired to have the tool follow.

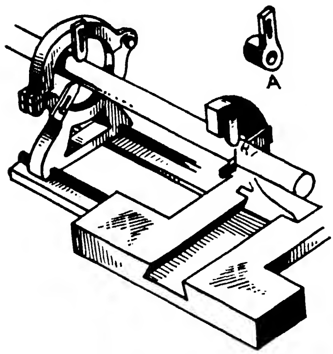


Fig. 45.—Steady and follow rests.

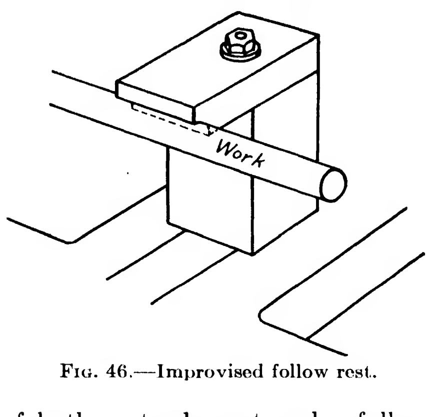


Fig. 46.—Improvised follow rest.

An outline of both a steady rest and a follow rest is shown in Fig. 45. The follow rest is fastened to the tool carriage and moves with it. In some cases it is found best to have the work supported by a bushing as at *A*; this bushing fits into one of the jaw slots in the follow-rest frame. Where a follow rest is not part of the lathe equipment, one can easily be improvised: Taking a block of wood of a length equal to the distance from

the top of the lathe carriage to the center of the work, one puts another piece at right angles to it, as shown in Fig. 46, for supporting the work. With the upper piece made of hard wood and cut out to the approximate radius of the work being turned, this makes a very acceptable follow rest for either plain or thread work. The block is, of course, fastened to the carriage, over the cross-slide ways, as with the regular type of follow rest.

Expanding Mandrels for Lathe Work.—Expanding mandrels can be very useful in many kinds of lathe work. They are much better than solid mandrels for all work except where there is a large quantity of work of the same size. Even here the solid

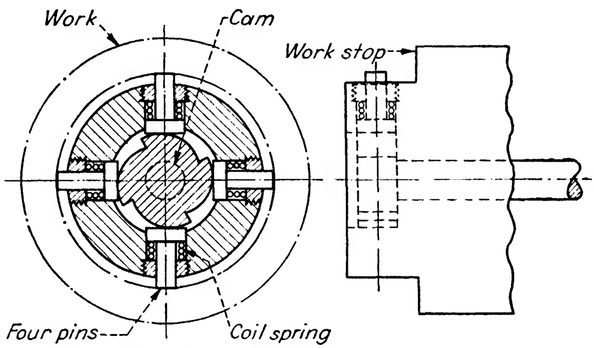


FIG. 47.—A pin-type mandrel with pins forced out by a cam.

mandrel may wear below size, or slight variations in bore, well within the tolerance, may prevent the kind of fit that is best in work of this sort.

Two types of mandrel used by the Cleveland Pneumatic Tool Co. are shown by John G. Jergens in the illustrations that follow. In one type a tapered rod or cam is used to force pins or keys outwardly against the bore of the work. In the other a sleeve or bushing is expanded by forcing a tapered plug into it. Several examples of each type are shown in Figs. 47 to 55.

The first two illustrations show mandrels of the pin type, the first having four pins which are forced out by a four-lobed cam. The pins are forced inward by coil springs acting between the head of the pin and a nut screwed into the mandrel as a guide for the pins themselves. A shoulder on the mandrel serves as a work stop and locates the work square with the center of the lathe.

In Fig. 48 a push rod with a tapered end acts against the coned

ends of the four pins and forces them out against the work. The movement of the pins is limited by screws which enter a slot in the side of the pin. In this particular mandrel the push rod was operated by hydraulic pressure, but it could be forced out by hand through any other means.

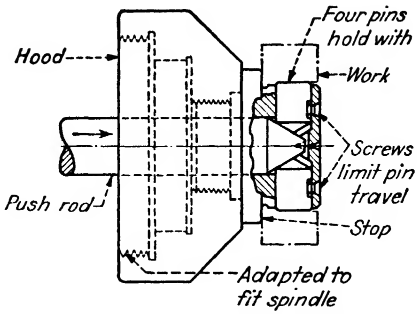


FIG. 48.—Here the four pins are forced out by a push rod with a coned end.

Figure 49 shows the familiar split sleeve which is expanded by coned surfaces at each end. The sleeve in this case only has the slots extending to the center which would tend to make most of the expansion come at the ends. Another somewhat similar

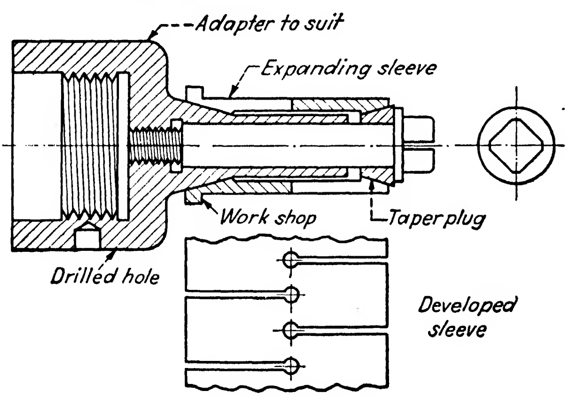


FIG. 49.—A split-sleeve type of mandrel.

sleeve is shown in Fig. 52, but this makes all the expansion at the ends, which is not usual practice.

Another expanding sleeve mandrel is shown in Fig. 50. This is for a cup-shaped piece of work and has a stop collar at the end which bottoms inside the work. This sleeve is expanded by

forcing the inner cone into the sleeve by means of a pin wrench. The small Woodruff key permits end movement of the sleeve but does not allow it to turn on the taper plug. The expanding sleeve has four slots.

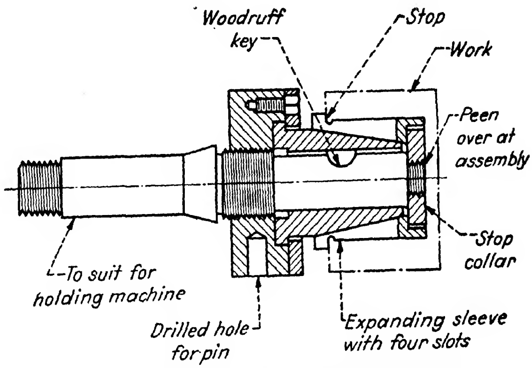


FIG. 50.—Another expanding-sleeve mandrel.

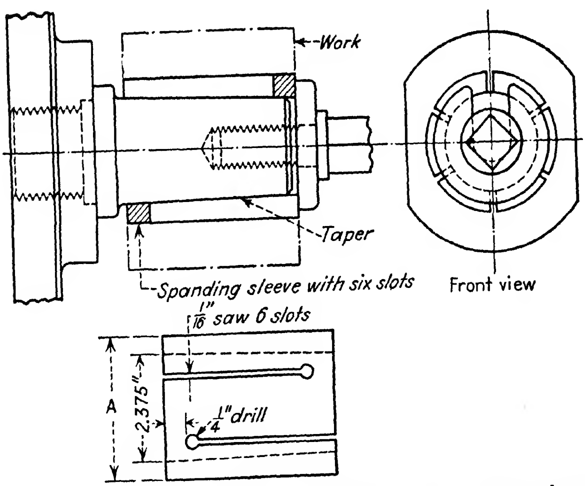


FIG. 51.—Expanding sleeve is forced on tapered plug by screw at the end.

Four other types of expanding mandrels are seen in Figs. 51 to 55. In Fig. 51 the sleeve is forced on the tapered plug by the screw at the end. In Fig. 54, this is reversed and the tapered member is drawn inside the expanding sleeve by the nut at the

back. This is also made for a special job as both ends of the inner member are provided with centers to locate the work in the lathe. The collar, at the left of the expanding bushing or sleeve, locates the work in proper position.

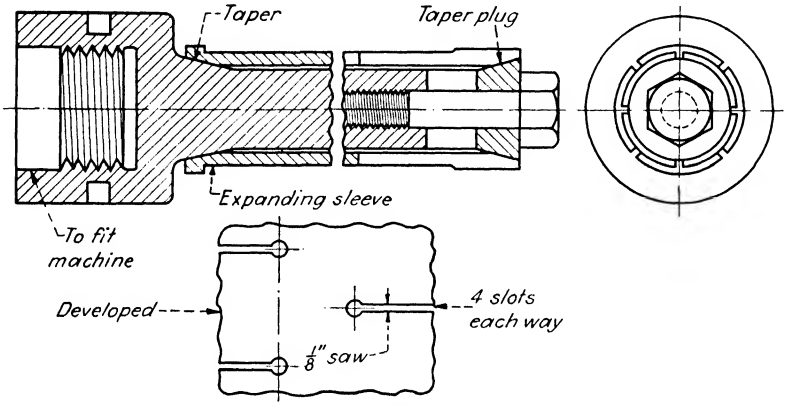


FIG. 52.—Only the ends of sleeve are expanded—making a two-point contact in work.

In Fig. 52 only the ends of the sleeve expand and provide a two-point contact inside the work. Figure 55 has the peculiarity of using a special flanged nut, the flange fitting in a groove in the

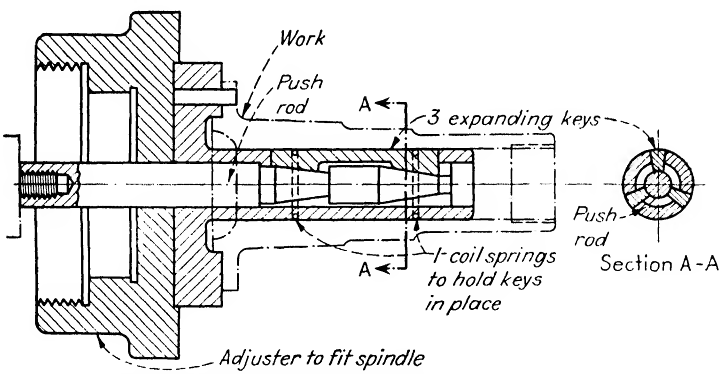


FIG. 53.—Three expanding keys are held by coil springs at each end. Two cones ensure equal expansion.

outer taper member to draw it out of the sleeve as well as to force it in. This eliminates any tendency to stick and saves time in handling it in the work.

Still another type of expanding mandrel is seen in Fig. 53. Here again three expanding keys are used, these being kept in place by two coil springs on the outside. Two tapers are

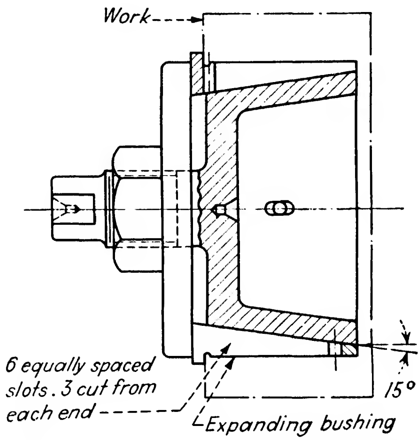


FIG. 54.—Here a lip on inside of work prevents end movement.

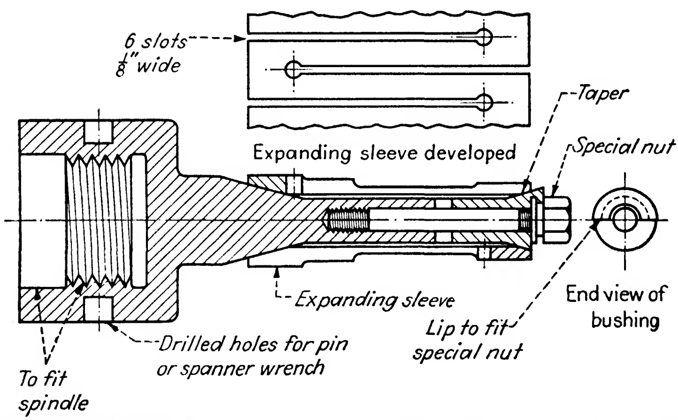


FIG. 55.—A special flanged nut on the end moves outer cone in both directions.

provided so that both ends of the keys are forced out at the same time and to an equal amount.

Mandrels to hold almost any kind of work can be made from some of the types shown.

CHAPTER IV

TAPERS—TURNING AND BORING IN THE LATHE

For lathes without taper-turning attachments, it is necessary to set the tailstock, or dead center, off center. This offset is one half the amount of the total taper. The first thing to consider is just what the taper is, as this is sometimes a point for differences of opinion. Some measure the taper on each

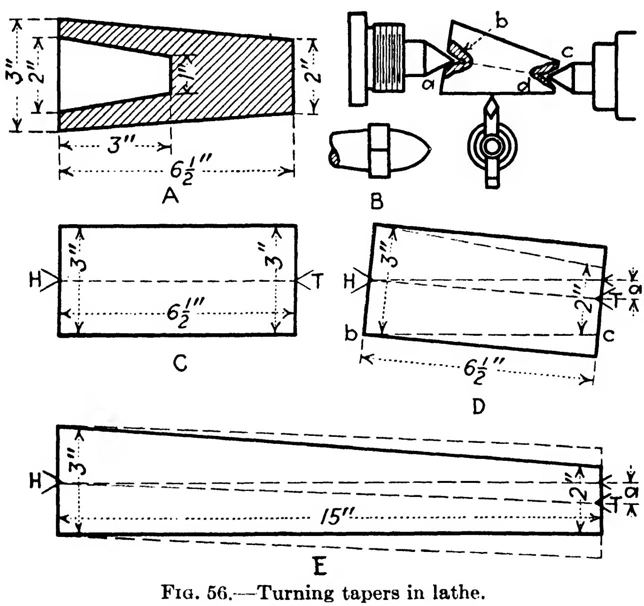


FIG. 56.—Turning tapers in lathe.

side, while the usual way is to take the total taper, as with pipe threads. The standard pipe taper is $\frac{3}{4}$ in. to the foot, which is the same as $\frac{1}{16}$ in. to the inch, or 1 in. in 16 in.

The amount of taper depends on the diameter at the two ends of the taper part of the bar and on the length of the taper, but the amount of offset for the tailstock depends on the length of the *whole bar* regardless of how much is turned taper. In

Fig. 56, *A* is a section of a taper plug with a taper hole. The difference in diameter is 1 in. in both cases, but the taper of the hole is much sharper, as it is less than half as long as the plug. The outside is 1 in. taper in 6½ in., while the hole is 1 in. in 3 in.

Setting over the Tail Centers.—The depth to which the centers enter the work affects the setting over of the tailstock and the taper. But as it is practically out of the question to set it over the exact distance the first time in any case, this need not enter into the question for general work. At *B* is a very short piece being turned to a sharp taper. It can be seen how the outer edge *a* and the point *b* bear on one end; on the other it is opposite, as in *c* and *d*. This is very hard on centers and makes it difficult to keep them from wearing.

Disregarding the center and its action and considering that the work is held between the points of the center as in *C*, *H* being the head and *T* the tail center, how much must we set the tailstock *T* over to cut the outside taper shown in *A*? This is 3 in. at one end and 2 in. at the other; therefore we must reduce the small diameter 1 in., which means ½ in. on a side, and we set the tailstock over ½ in., as at *a* in *D*. The tool moves along the line *bc* and cuts off ½ in. at the small end, running out at *b*. If the tailstock has been set over just ½ in., the outside will be the correct taper, as shown by dotted lines.

In *E* the tailstock is set over the same amount and the small end reduced to 2 in. as before; but as the piece is 15 in. long instead of 6½ in., the taper per inch or per foot is very much less.

In Fig. 57, *A* shows a straight bar in the lathe before setting over the tailstock; *B* with tailstock set over and *C* with the bar turned to the desired taper. If this bar is 3 in. in diameter and 30 in. long, how much must it be set over to make a taper of 2 in. in 24 or within 6 in. of the whole length?

As the taper is 2 in. in 24 or 1 in 12 in. or $\frac{1}{12}$ in. in 1 in., in 30 in. it would be $\frac{30}{12}$ or 2½ in.; so the tail center must be set over one half of this, or 1¼ in. An example of this work is in turning the taper on the end of a piston rod, where the taper may be 6 in. long and perhaps an inch to the foot, as in the above case. The rod may be 48 in. long, and the whole length must be considered in setting over the tail center. In 48 in. the taper would be $\frac{48}{12}$ or 4 in., so that the tailstock would have

to be set over 2 in. The two points to remember are the getting of the right taper and *always to consider the total length of the piece regardless of the length of taper portion.* It makes no difference where the taper portion is, whether at the tail end, the middle, or near the headstock, the set-over is the same in any case.

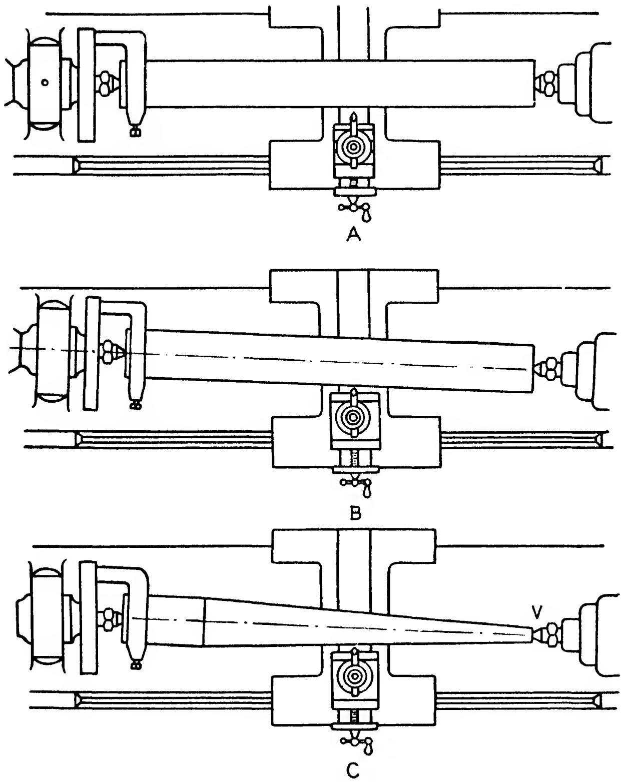


FIG. 57.—Setting over the tailstock.

It is generally easier to figure tapers if we reduce them to the amount per inch in order to get at the offset. If the taper is given per foot, we divide it by 12, as, if it is pipe-thread taper of $\frac{3}{4}$ in. per foot, we have $\frac{1}{12}$ of $\frac{3}{4}$ or $\frac{3}{48}$ or $\frac{1}{16}$ per inch. If the taper is given 1 in 8 or 1 in 15, the taper per inch is, of course, $\frac{1}{8}$ or $\frac{1}{15}$ in. to the inch.

Tapers are frequently given in degrees, and in such cases they are usually turned with a compound rest divided into degrees; but it is sometimes handy to know what the taper would be in inches. Table II will help if the taper is marked in degrees and Table III when the taper is given in inches per foot.

TABLE II.—TAPERS IN DEGREES AND INCHES PER FOOT

Total taper, deg.	Equivalent taper, per foot	Set-over tailstock or taper attachment per inch of length
1	0.20952	0.00873
2	0.41904	0.01745
3	0.62832	0.02618
4	0.83808	0.03490
5	1.04688	0.04362
6	1.25664	0.05234
7	1.46520	0.06105
8	1.67616	0.06976
9	1.88496	0.07846
10	2.09376	0.08716
11	2.31040	0.09585
12	2.51328	0.10453
13	2.71680	0.11320
14	2.93140	0.12187
15	3.14064	0.13053

TABLE III.—TAPER AND SET-OVER FOR TAILSTOCK

Total taper, in. per foot	Set-over tailstock or taper attachment per inch of length
3/32—0.09375	0.0039
1/8—0.125	0.0052
3/16—0.1875	0.0078
1/4—0.25	0.0104
3/8—0.375	0.0156
1/2—0.5	0.0208
5/8—0.625	0.026
3/4—0.75	0.0312
7/8—0.875	0.0364
1—1.	0.0416
1 1/4—1.25	0.052
1 1/2—1.50	0.0624
1 3/4—1.75	0.0728
2—2.	0.0832

Measuring Tapers in the Lathe.—Table II shows that to cut a taper of 4 degrees on a bar 12 in. long means a total taper of 0.838 in., and that the tail center must be set over practically 0.42 in. A taper attachment is set over the same amount, as in Fig. 58.

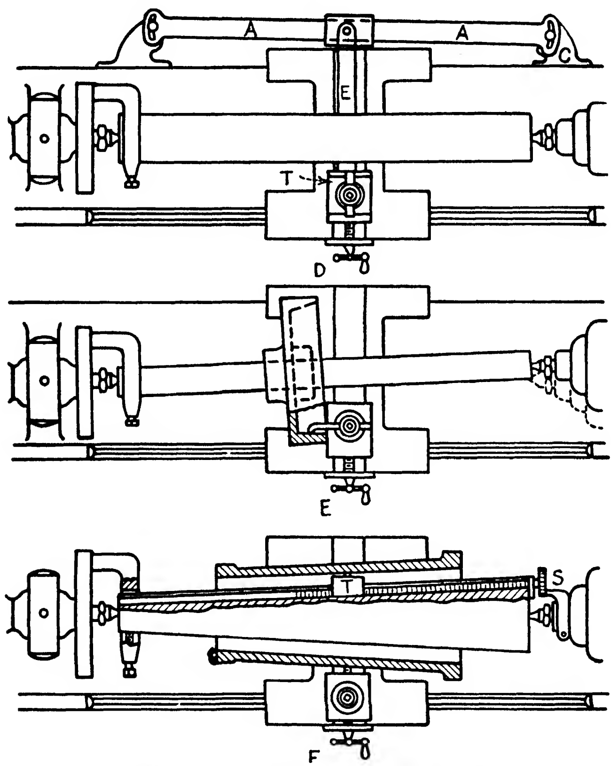


Fig. 58.—Other methods of taper work.

Using the Taper Attachment.—Many lathes have a taper attachment consisting of a bar at the back *A*, on which a shoe slides and moves the tool block *T* through the link *E*, as shown by *D*, in Fig. 58. The cross-feed screw is, of course, disconnected so that the tool block is free to slide under control of shoe. Blocks as at *C* are fastened to the back of the lathe and hold the ends of the bar *A*, as shown, at any desired angle, the angle of the bar giving a similar taper to the work. As shown, the

bar would be turned smaller at the head end than the tailstock—just the reverse of the usual way.

These bars are graduated at the ends, sometimes in inches and fractions, sometimes in degrees, sometimes inches at one end and degrees at the other. Some lathes have the bar swing from one end only. This plan allows a much better contact of the centers in the work and has many advantages. Credit for this device belongs to Dwight Slate, of Hartford, Conn., who brought it out in 1867.

Boring Taper Holes.—Most taper boring is done with a compound rest, the piece of work being held in a chuck or strapped to the faceplate and the outer end supported in a steady rest. But there are many jobs which can be handled by driving the work on an arbor or mandrel, as in *E*, Fig. 58, and setting the arbor over just as though that were the piece to be tapered, except that, for boring, the tailstock must be set over the other way, as will be seen in the illustration. This is a pulley for a fraction-clutch countershaft, and is bored with a regular lathe tool.

If the taper is 1/8 in. to the inch and the arbor 24 in. long, the total taper would be 3 in. and the offset one half of this, or 1 1/2 in. With a shorter arbor, say 16 in., the offset would be only 1 in. and so on.

Use of Boring Bar.—Long taper holes are sometimes bored by using a star-feed boring bar. The tailstock is not set over in the case shown where a tapered bar is used. The bar is driven from the faceplate as in Fig. 58. It is also possible to bore taper holes with a straight bar with the work driven by the faceplate and the bar offset to the right taper by the tailstock. The tool must be fed along the taper desired. The work does not turn in this case, but is held stationary on the carriage. The star feed must be operated by a pin fastened to the tailstock as shown. As the bar revolves, the star wheel strikes the pin and turns the feed screw that moves the tool *T* along the bar (Fig. 58).

Cutting Taper Threads.—When it comes to cutting a taper thread, there is a difference of opinion as to the correct method.

In straight work we set the threading tool square with the surface to be threaded; some do this with tapered work as well. It is easier but not right, as will be seen at *A*, Fig. 59. This makes the front side of the thread almost at right angles to the

center line, and the back of the thread becomes more nearly parallel and has a very poor hold on the other piece which screws into or on it. The angles would vary with every taper, being less objectionable as the taper decreases.

The proper way is to set the thread tool at *right angles with the center line* of the piece, as shown at *B*, as this gives an equal angle to both sides of the thread, although the back side is necessarily shorter than the front; but it will hold better than the other. All pipe threads are cut in this way.

To do this, hold the thread gage in line with the points of the centers, either by holding a scale between the centers or in any other way that is easy. The tool is shown in position in both *A* and *B*, and the setting of the tool is important if good threads are wanted on the work.

The exception to this method of cutting threads at right angles to the axis is in threads used in some oil-well tools, such as the Hughes modification of the Acme thread. Here the thread is cut at right angles to the slope. The taper is 16 deg. total, or $3\frac{3}{8}$ in. per foot.

Points to Remember about Taper Work.—The main points about taper work are:

Always consider the length of the work or the distance between centers instead of the length of the taper portion.

Make the offset half the amount of the total taper.

Always set the point of the tool at the height of the lathe center in taper work. If it is set above or below the center, there will be a slight change in the taper as the diameter is reduced. This is a very important point to remember.

In cutting taper threads, set the tool square with the center line of the work and not square with its surface, except for the Hughes thread. Set it at height of center.

It is always well not to set the tailstock over the full amount at first, so that the small end will be larger than required, rather than smaller.

In making long taper fits it is easier to have the bearing for a short distance on each end with a relief in the center, and this generally answers the purpose equally well.

Gage for Setting Lathe Tools.—The gage illustrated in Fig. 60 is for setting lathe tools in relation to the center height of the lathe. Essentially, it consists of the rectangular steel block *A*

having an angular opening at *B*, the adjustable gage *C*, and the spirit level *D* at the top.

In use, with the device correctly adjusted and held against the work as shown, the under side of the lip on gage *C* resting on top of the tool, the tool is at center height when the level bubble is central between the lines *F* and *H* etched on the glass. If the bubble is out of center toward the work, the tool is below center height. If the bubble is out of center away from the work, the tool is above center height. Thus, the device can be used to set the tool at, above, or below center height.

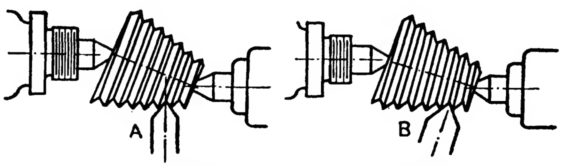


Fig. 59.—Setting tools in taper-thread work.

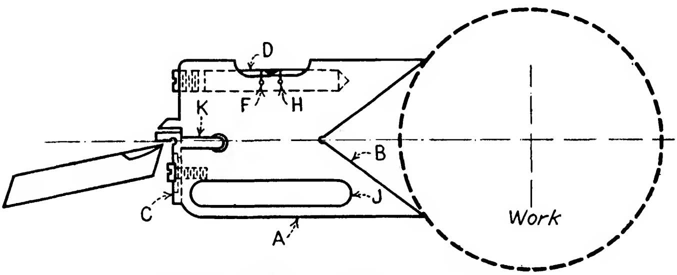


Fig. 60.—Gage for setting tool at center.

The device is usually held against the work by the left hand, the fingers grasping by the milled depression *J*, while the tool is adjusted with the right hand. It is sometimes convenient to hold the device against the work by a rubber band looped about the work, the loops at the free ends being caught in the slot *K*, leaving both hands free.

Setting Compound Rests.—The difficulty experienced in measuring angles and setting dividing heads and compound rests comes mainly from two causes: A confusion of ideas as to whether half of the total angle is meant and the position of the base line.

In the compound rest we have the work measured in angles from a line drawn between the lathe centers while the slide is at

right angles to this as in A, Fig. 61. If we have to turn the bevel on a valve-seat reamer that is 60 deg. total angle, we must set the slide rest at 30 deg. from the line of the centers. This very seldom means that we can set it to 30 deg. on the compound

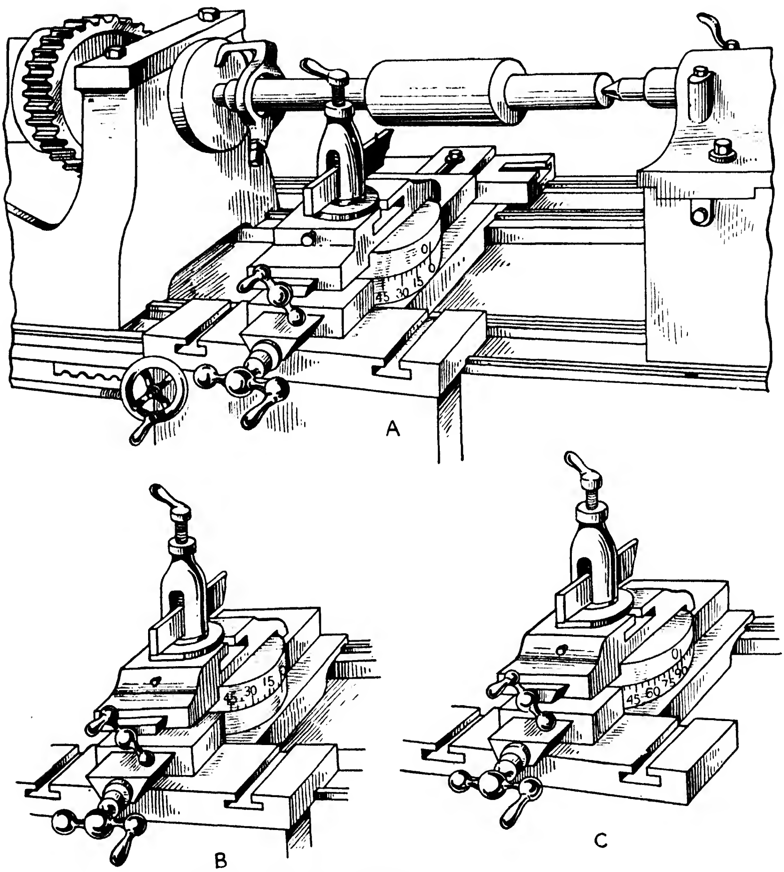


FIG. 61.—Setting angles on compound rests.

rest as they are usually divided to read from the cross movement at right angles to the center.

Perhaps the easiest way is to swing the compound rest parallel to the lathe centers with the handle toward the headstock, and the two 45-deg. marks come together if they are divided in this way. Then move the handle end out until 30 deg. have passed

by the 45-deg. mark, or until 15 deg. on the upper coincides with the 45 if both are graduated. No matter how it is divided, move the compound rest 30 deg. without regard to the numbers as they appear.

When facing work to any desired angle and the work is normally in line with the cross slide, read the divisions just as they are graduated, bearing in mind that each degree the slide is set off means 2 deg. total angle for the work.

A, *B*, and *C*, Fig. 61, show three methods of graduating compound rests on a lathe or swivel head on a planer. In *A* the base is divided into 45 deg. each side of a zero line at the side or at right angles to the cross slide. With this graduation the scale shows the degrees moved through by the tool slide with reference to the cross slide. If we set it to 15 deg., we can face off a piece 15 deg. on each side of the end, but this would leave the end with a total angle of 150 deg. with the center line of the work.

In *B* the graduations are reversed, being on the upper slide, and the zero on the base. The results are the same except that we read on the opposite side of the zero mark of the graduations; swinging the upper slide to the left 15 deg., we must read the angle on the side of the scale now hidden from view.

C shows a different plan and one which has some advantages to recommend it: the 90-deg. mark in place of the zero, in *A*, the 75-deg. in place of the 15-deg. mark, but, of course, the 45-deg. mark comes in the same place on account of its being halfway between the two.

This method of graduation shows the exact angle that will be cut each side of the center line, and we get the total angle by doubling the figures of the graduation. If we move it to 75, it will cut 75 deg. each side of the center line. If it is moved to 45, it cuts a 90-deg. total angle, and if to 60 it cuts 30 deg. away on each side, leaving 120 deg. included angle. Bearing this in mind, there should be no confusion as to what angle will be cut.

After one becomes familiar with the divisions of the machine he is handling, it is easy to set by the numbers, but as they are apt to be confusing, it is safer to check the reading by counting the degrees from the point when the slide is parallel with the lathe centers.

Table IV gives the tapers most commonly used in both degrees and inches per foot. It will save time and trouble in figuring out the desired taper.

TABLE IV.—A TABLE OF COMMON TAPERS

Taper per foot	Angle B		Taper per foot	Angle B		Taper per foot	Angle B		Taper per foot	Angle B	
A	Deg.	Min.	*A*	Deg.	Min.	*A*	Deg.	Min.	*A*	Deg.	Min.
1/8	0	36	1 5/8	8	53	5 1/4	23	38	8 3/4	36	6
1/4	1	12	2	9	28	5 1/2	24	37	9	36	53
3/8	1	47	2 1/4	10	37	5 3/4	25	36	9 1/4	37	36
1/2	2	23	2 1/2	11	46	6	26	35	9 1/2	38	21
5/8	2	59	2 3/4	12	54	6 1/4	27	30	9 3/4	39	5
3/4	3	35	3	14	2	6 1/2	28	25	10	39	48
7/8	4	10	3 1/4	15	9	6 3/4	29	21	10 1/4	40	30
1	4	46	3 1/2	16	16	7	30	15	10 1/2	41	12
1 1/8	5	21	3 3/4	17	21	7 1/4	31	8	10 3/4	41	52
1 1/4	5	57	4	18	26	7 1/2	32	1	11	42	32
1 3/8	6	32	4 1/4	19	30	7 3/4	32	50	11 1/4	43	9
1 1/2	7	7	4 1/2	20	33	8	33	43	11 1/2	43	47
1 5/8	7	43	4 3/4	21	36	8 1/4	34	30	11 3/4	44	24
1 3/4	8	18	5	22	37	8 1/2	35	18	12	45	0

It is frequently necessary to set the compound rest more accurately than can be done by the graduations on the base. A toolmaker, W. F. Hoag, uses the following method:

Set the compound rest at zero and be sure it is at exact right angles to the ways of the lathe. Drill and ream a hole, 1/2 in. is a good size, in both the base and the swivel, and in line with each other as in Fig. 62. Press a ground and lapped plug in each hole, as at *A* and *B*. The plugs should be necked down, near the end, leaving a narrow land, as at *C*, for micrometer anvils to contact. These lands should not be over 0.01 in. wide and should be ground to as near 1/2 in. diameter as possible. They should have about 0.01 in. clearance between the ends.

To set the compound rest 28 deg. 30 min., divide this by 2 and look for the sine of 14 deg. 15 min. in a table of natural sines. This is 0.246. As the sine is half the chord, which is what we measure on the pins, multiply this by 2 and get 0.492, the chord of the angle of 28 deg. 30 min. on a 1-in. radius. By making the holes for the pins an even inch distance from the

center on which the compound rest turns it is easy to multiply the chord for 1 in. If the pins are 4 in. from the center, multiply 0.492 by 4 and get 1.969. As we measure over the pins, add the diameter of one pin, or ½ in., making the distance 2.469 in. Set the compound rest so that the pins read 2.469 in. and the angle is 28 deg. 30 min.

Turning Special Tapers.—Turning tapers with the compound rest on bench and other lathes may require a little study to secure just the desired results. In some cases the ball cranks of the cross slide and the compound slide interfere with each other when the compound is set beyond 50 or 60 deg. For angles

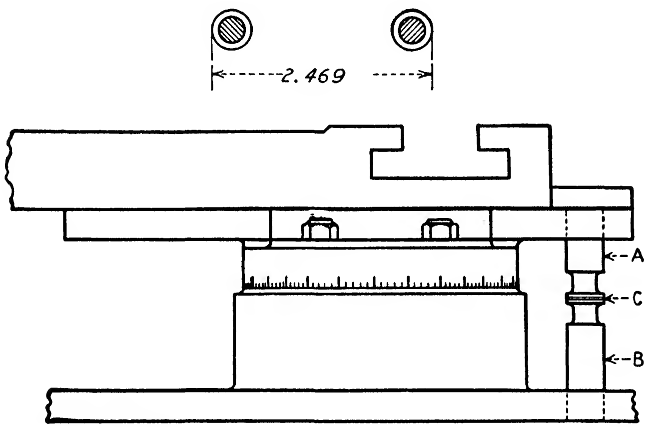


Fig. 62.—Setting compound rest accurately.

beyond compound graduations, the cross slide can be used to turn the taper and the compound slide for the cylindrical turning.

In the illustrations shown the compound slide is used to turn the outside of the piece, this being set parallel with the lathe ways after the cross slide has been set to the required angle of 10 deg. The cross slide is set with the aid of a bevel protractor to give 80 deg. between the two slides, which makes the cross slide 10 deg. out of square with its normal position.

In Fig. 63 an indicator is being used to check the cross-slide setting with the cylindrical portion of the work. In Fig. 64 the cross slide is being used to turn the 10-deg. concave surface in the end of the work.

With the cross slide at an angle, the graduations on the screw do not give the amount of metal removed from the outer diam-

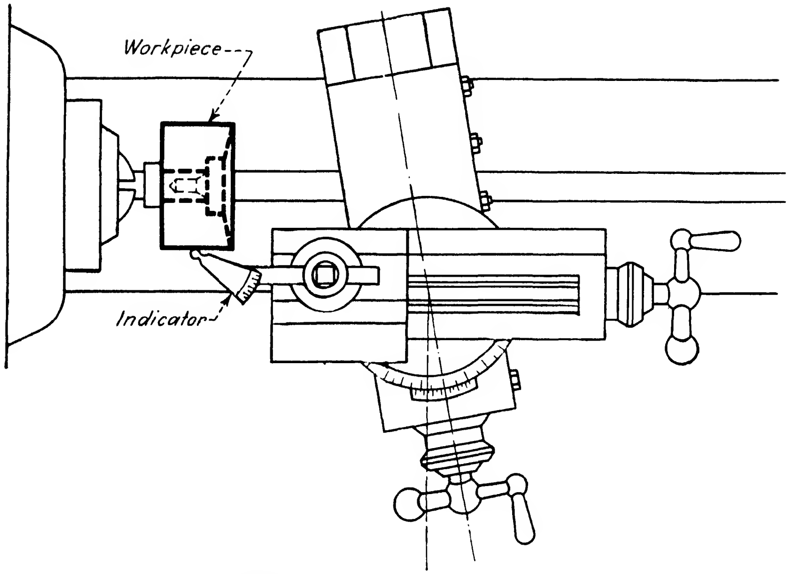


FIG. 63.—Using indicator to check cross-slide setting

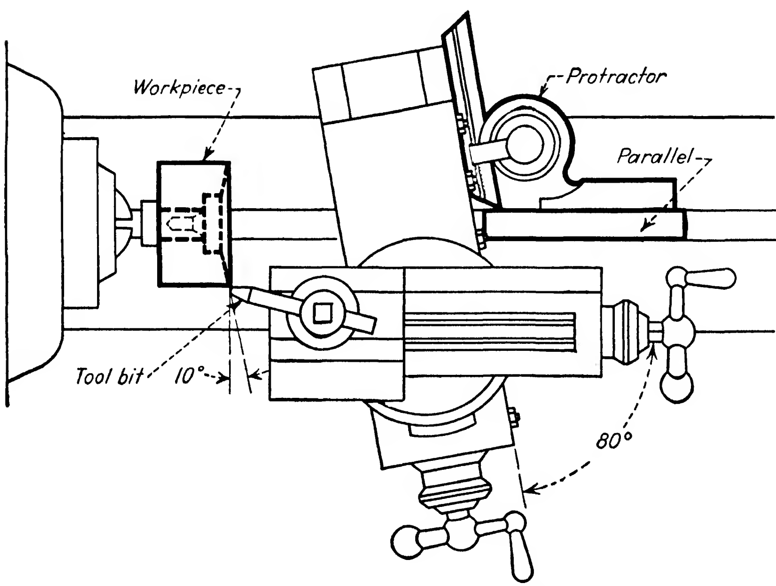


FIG. 64.—A protractor checks setting for a 10-deg concave surface.

eter, this varying with the angle at which it is set. This is shown in Fig. 65.

Here a = forward movement of the tool with cross slide used at an angle.

b = depth of cut, equal to half the distance of the diameter, before and after the cut is taken.

c = cross-slide movement.

Then

$$a = b \times \text{tangent of } A$$

$$b = \frac{\text{diameter before cut} - \text{diameter after cut}}{2}$$

$$c = b \times \text{secant } A$$

Then

$$a = \frac{0.100}{2} \times \text{tangent of 10 deg.} = 0.0088 \text{ in.}$$

$$b = \frac{0.100}{2} = 0.050 \text{ in.}$$

$$c = 0.050 \times \text{secant of 10 deg.} = 0.05077 \text{ in.}$$

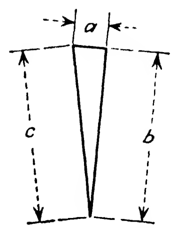


FIG. 65.—This shows the difference between the depth of cut b and the cross-slide movement c.

This shows that there is little difference at a 10-deg. angle but that it increases as the angle is increased. It may be easier to measure the diameter than to try and use the graduations on the screw.

CHAPTER V

THREAD CUTTING

There is nothing mysterious about thread cutting. The thread tool must move the amount of the pitch, or distance between threads, at every revolution of the work. This is done by using suitable gearing between the spindle and the lead screw. By selecting gears with the right number of teeth, the proper tool movement is obtained, to cut the thread desired.

If the lead screw is geared "even," that is, if it makes one turn for each turn of the spindle, we will cut the same thread in the lathe as there is on the lead screw. For if the lead screw is six threads to the inch and makes one turn to each turn of the spindle, the carriage and the tool must move $\frac{1}{6}$ in. for each turn of the spindle.

To test this, put gears having the same number of teeth on both the stud and the lead screw and see if you cut the same thread as the lead screw. If not, take the *thread cut* as the true pitch of the lead screw in all calculations to be made.

Having found what thread will be cut with "even" gears, it is easily seen that to cut a coarser pitch thread, the lead screw must be driven *faster* than the spindle, while to cut a finer pitch, the lead screw must run *slower* than the spindle. This means that for a finer pitch the larger gear must go on the lead screw, and for a coarser pitch the small gear goes on the lead screw.

Calling the lead screw six-pitch and wanting a three-pitch thread, the lead screw must turn twice as fast as the spindle, so that the stud gear must have twice as many teeth as the screw gear. This means that a 24-toothed gear on the lead screw and a 48 on a stud would cut a three-pitch thread on the work. If, on the other hand, a 12 thread is wanted, the screw must turn half as fast as the spindle, so that the same gears can be used, but the 48 goes on the lead screw and the 24 on the stud.

Figuring Change Gears.—There are many ways of figuring gears, but they are all based on the ratio or proportion between

the movement of the thread tool and the revolutions of the lathe spindle.

With the principles on which screw cutting is based fixed thoroughly in mind, any job of thread cutting can be handled without difficulty.

Perhaps the easiest rule is to multiply both the thread to be cut and the pitch of the lead screw by any number (the same number in both cases) that will give gears found in the set. If the lead screw is 4 to the inch and we wish to cut a 10 thread, multiply both 4 and 10 by any number such as 6, giving 24 to 60; or by 5, giving 20 to 50. Put the gear obtained by multiplying the thread to be cut, on the lead screw, and the other on the stud. The reason for this is that the thread to be cut depends directly on the revolutions of the lead screw. When the thread to be cut is finer than the lead screw, it is clear that the lead screw must turn slower than the spindle, so the larger gear goes on the lead screw.

This shows us why we make the rules as follows:

1. *To find the gears for cutting any thread.* Multiply the thread to be cut and the lead screw by any number that will give two of the gears in the train. Always multiply both the thread to be cut and the pitch of the lead screw by the same number. Put the gear found by multiplying the thread to be cut on the lead screw and the other on the stud.

2. *To find what thread will be cut by any pair of gears.* Multiply the pitch of lead screw by its gear and divide by the gear on the stud.

3. *To find gears to cut a thread faster than* 1 *to the inch.* Divide the distance between one complete turn by the distance between threads in the lead screw. This shows how many times the lead screw must turn for each turn of the spindle. Use gears that will do this and you are all right.

Examples.—Lead screw 5 to inch to cut a 12 thread. Multiply both by 5. $5 \times 5 = 25$, the gear for the stud. $5 \times 12 = 60$, the gear for the lead screw.

What thread will be cut by a 64 gear on lead screw, 48 on the stud and lead screw 4 to inch?

Multiply 64 by 4 as in Rule 2, and divide by 48. $64 \times 4 = 256$. Dividing by 48 gives $5\frac{1}{3}$ threads per inch. Prove this by Rule 1, using 12 as a multiplier.

What gears will cut a thread $1\frac{3}{4}$ in. pitch, lead screw 4 to the inch?

Lead-screw pitch = $\frac{1}{4}$ in. and $1\frac{3}{4}$ = $\frac{7}{4}$ so the thread to be cut is seven times as fast as the lead screw, and the lead screw must travel seven times as fast as the spindle. This will be impossible without compounding, in most cases.

Compounding Gears.—The compounding of gears is simply a way of avoiding the use of very large gears and of requiring a much larger number of gears in the set. If the lead screw is 4 to the inch and you want to cut a 36 thread, the screw must turn only $\frac{1}{9}$ as fast as the lathe spindle.

As the screw moves so much slower than the spindle, we must put the small gear on the stud. We seldom use a smaller gear than 24 teeth, and $9 \times 24 = 216$ for the gear on the screw. To avoid this, we use a compound gear set between the stud and the screw, varying the proportions of the compound gears as we think best.

In this case we can take a 24 and a 72, making a 3 to 1 combination, and reduce the motion between the stud and the screw to one third, so that we select the gear for a thread $\frac{1}{3}$ of 36, or 12. As 12 is three times the lead of the screw, the gear on the screw must be 3×24 or 72. So we have the 24-tooth gear on the stud mesh into the 72 of the compound, and the 24 of the compound mesh into the 72 on the screw.

Analyzing this, we can see that the 24 gear of the stud will turn the 72 gear of the compound just $\frac{1}{3}$ of a turn or 24 teeth. At the same time the 24 gear of the compound is also turned $\frac{1}{3}$ of a revolution or 8 teeth, and moves the 72 on the screw an equal amount, which is $\frac{1}{9}$ of the whole number of teeth or $\frac{1}{9}$ of a turn, so that the thread tool has only moved $\frac{1}{9}$ of $\frac{1}{4}$, or $\frac{1}{36}$ in.

The gear-feed boxes or quick-change devices for threads are simply combinations of compound gears which can be varied by sliding keys or by other means. These give a variety of gear combinations which can all be traced out in this same way with a little care, always remembering that there is nothing mysterious about any of them.

Most modern lathes have quick-change gear systems that make it unnecessary to change or calculate gears. But it is well to know how.

Catching Threads.—The time wasted in letting a lathe run the carriage back, even with a fast-backing belt, is not good practice on long threads. If we stop the lathe at any point on a

threading job, unlock the carriage and move it along just an inch, it will always catch the thread unless it is faster than one to the inch.

If both the pitch of the thread being cut and the lead screw are even numbers, such as 2, 4, or 6, the thread can be caught at any half inch. But the way to save time is to be able to do this without stopping the lathe or doing any measuring except with one's eye. Stopping the lathe with the dog in any particular position takes time and is unnecessary if one is careful and gets a little practice.

If the lathe is geared even, or the work being threaded is the same pitch as the true pitch of the lead screw, one can throw in the half nut anywhere and have no fear about catching the thread. This is also true if the thread being cut is any multiple of lead screw, but we must find a way to catch any threads that come along and do it so as to save time and yet not spoil work.

When starting the thread, it is a good plan to note the position of the lathe dog, turning it until its tail is at the top. Then the thread-cutting tool is brought as near the starting point as is thought safe and the half nut is locked in. Now the tailstock body is moved up till it touches the carriage bridge, or something is put on the bed that will give a positive indication; and we are ready.

It is very evident that whenever the lathe dog has its tail at the top and the carriage is back in the same position, the half nut will drop into place and catch the thread every time. So all we have to do after a cut is to open the half nut, run the carriage back to the stop or mark as the case may be, wait until the dog's tail gets to the top, and close the half nut. It doesn't require that you wait till it is exactly at the top, as the eye can tell near enough to enable the half nut to catch in at the right place, for the lead screw threads are so coarse that if the nut goes in when the dog is near the top it is all right.

Another way, not quite so rapid as the one just described, is to run the carriage back until the thread tool is near the beginning of the cut, and run it in until it nearly touches the work. Then with the half nut in hand ready to close, wait till the thread tool points to its proper position in a thread, throw in the nut, and the carriage will start in its proper place. Reverse the lathe, run it back a turn or two till the tool clears the work, and then start

the cut. But the other way is quicker and better in most cases.

Many lathes now have a thread-catching indicator, that shows when to close the half nut.

Rapid Thread Cutting.—Thread cutting used to be considered a ticklish job and light cuts were in order, but a good lathe man can chase threads at a rapid rate.

An example of this is a lot of special studs, where the threads were 7 pitch, 1⅛ in. in diameter, and the thread was 2½ in. long. These were chased in an engine lathe with a single-point tool in from 4 to 5 cuts by a boy who has learned to catch threads quickly, at the rate of 13 studs an hour.

There is a little trick about this that is worth knowing. The first chip was a reasonably heavy one, perhaps half the depth of

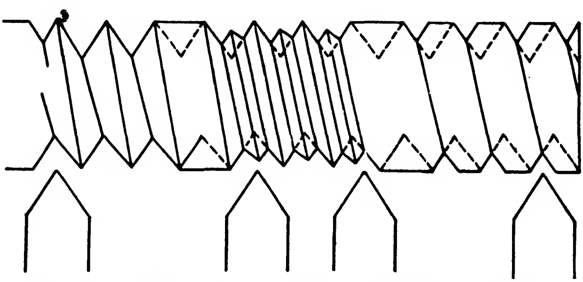


Fig. 66.—Cutting threads rapidly by splitting the cuts.

the thread because the area cut out is comparatively small. Then on the next cut he deliberately missed the first thread and cut another the same depth as the first, as shown in Fig. 66. The next time he split the two cuts and took out another big chip from the center, getting the thread down nearly to size, avoiding the heavy crowding chips from both sides as when cut straight down from the center every time. The fourth or fifth chip finished the stud to size and left a good thread.

Measuring the Thread.—The old method of measuring the thread with a pair of broad-nosed calipers to go over two or three threads has given way to the better plan of measuring halfway down the sides of the thread. Measuring the top gives the outside diameter, but the threads should fit on the sides and not the top or bottom.

The bottom of the thread depends entirely on the point of the thread tool, while the top depends on whether the cut is brought

up so as to be just sharp in a V thread or to just the right width of flat for the American Standard. But measuring the sides of the threads is much more accurate.

The most refined and accurate thread measurements are made by the use of wires laid in the threads, then the outside of the wires measured by micrometer or else a special thread micrometer. Details of this method will be found in the "American Machinists' Handbook." But for lathe work, some use a pair of calipers, with points ground so as to touch the sides of the thread about half-way down. They can be set to a bolt that fits the nut properly. More accurate work can be done with a thread micrometer or snap gages.

Pitch and Lead.—Before starting to cut any threads, it is best to fix in the mind what the pitch of a screw is. As usually meas-

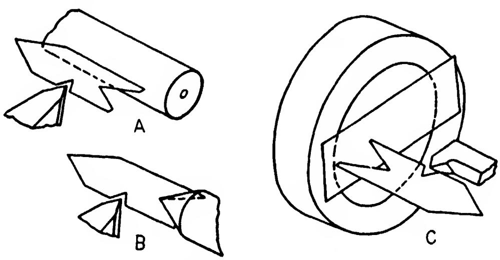


FIG. 67.—Using gage for setting thread tools.

ured, we say 10 pitch, meaning 10 threads to the inch. On the other hand, we sometimes run across a drawing marked ¾ pitch, which should mean three-quarters of a turn to the inch or one turn in 1⅓ in. If it says ¾ *inch* pitch it means ¾ in. from one thread to the next.

The next point to watch is "pitch" and "lead." The *pitch* of a thread is the distance from the center of one thread to the center of the next. The *lead* of a screw is the distance a nut will advance in one revolution of the screw. If it is a single-thread screw, the pitch and lead are always the same; but for double, triple, or any multiple thread, the lead is just as many times the pitch as there are multiple threads. A double thread has a lead twice the pitch, a triple screw three times, and so on. The pitch might measure 12 with a screw thread gage, but be a quadruple thread of 3 to the inch. The helix angle that the thread makes with the bar on which it is cut tells the story here.

Grind your tool to fit the thread gage and set it square with the work, as shown in Fig. 67. This insures each side of the thread being 30 deg. The tool can be set on straight work by resting the back side of the gage against the work and using the small V on the side to see that it is right as at *A*, Fig. 67. Some place the large V in the end over the center, as shown in *B*; but the first is usually the better way. For inside thread cutting the tool can be set as in *C* if the work is small, or by reversing the process of *A* if the hole is large enough.

Thread tools should be set at the center and have no back rake, when used for finishing cuts.

Cutting the Thread.—Having found the proper gears for the thread wanted, either by figuring out the change gears or by moving the handle in the gear box if the lathe has one, the next

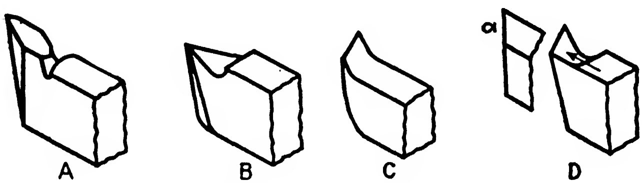


FIG. 68.—Forms of threading tools.

step is to decide on the tools to use. In some cases men seem to forget all about the question of clean cutting when it comes to thread tools, and grind up a tool to fit the thread gage without regard to top rake or easy cutting. In cutting brass the top rake can be omitted, but for iron and steel it will help in roughing out a job quickly and getting ready for the finishing cuts.

An old standby for a roughing thread tool is shown in *A*, Fig. 68. This is practically a diamond lathe tool, with the sides 60 deg., plenty of top rake, and the point rounded so as to stand a heavy chip. For soft steel or wrought iron this will get out most of the metal in a few cuts and leave the finishing for a tool like *B*, which, from the amount ground down on top, has seen service.

Some prefer a bent thread tool, and this is necessary at times to get up close to a shoulder. These tools are usually bent around as at *C* or even more than this, but an easier way is to grind the end of a straight bar as shown at *a*, in tool *D*, which is an easy tool to make and gets up to a shoulder very nicely. When

ground with plenty of top and side rake as shown, it looks like *D* and is an excellent tool for roughing out a coarse thread. For finishing threads the tool should be flat and radial from the center of the work, except in angular feeding. For securing a good finish on threads the last cuts should be about 0.005 in. deep.

Most shops now use one of the many threading tools with removable points, and these have the advantage of being able to reset the tool in the same place after grinding.

Take Up All Lost Motion.—One cause of unsatisfactory thread cutting is to have "slack" in the cross-feed screws or lost motion in the slides of the tool block or the compound rest. Any one of these is apt to allow the tool to dig into the work, which is exasperating especially if it is near the finishing cut. The slides should be gibbed down quite tight to be sure the slack is taken out of the screws, and the tool clamped tight and with as little overhang as possible, before starting to cut a thread.

Angular Feeding of Tools.—To get away from the wedging action of a V tool and to get the advantages of the side-cutting tool, some use what can be called the angular-thread-cutting method.

The object of this is to get the advantage of a side-cutting tool by feeding the tool into the cut so as to cut only on one side until the roughing is all done, and then finish with the regulation tool, cutting on both sides. It is possible, however, to cut the entire thread from one side if the tool is in good shape and fed in at exactly the right angle, or the last cut can be taken by feeding the cross slide in straight.

The swivel or compound rest is necessary for this kind of work, and it should be set at 30 deg., as shown in *A*, Fig. 69. This has the tool shown in *D*, Fig. 68, with the top ground away so as to give a side-tool rake from the cutting edge. The tool is fed up to the work by the regular cross slide, which should then be locked by tightening the gibs or in any other way, and the tool fed into the work by the swiveled slide. This makes the front or shearing edge do all the cutting, and it will be seen that the other edge of the tool simply follows the angle of the thread. The notches in work at *A* show different cuts and how the front edge does all the work, but still leaves a perfect thread at the bottom every time. Some consider this method best for nice work.

As a matter of fact, it is very hard to cut a V thread that is perfectly sharp at the bottom, and the roughing cuts should be taken with the point of the tool either rounded or flattened, saving the tool with a perfectly sharp point for the very last cuts, if a sharp V is wanted. The sharp V thread has, however, been discarded by nearly everyone.

Another way of using the compound rest in thread cutting is to set it at right angles to the cross slide, as shown at *B*, and move the thread tool first to one side of the thread and then the other, cutting on only one side at a time until the finishing cut. This method is said to be quite common in English shops. The thread is shown broken for clearness.

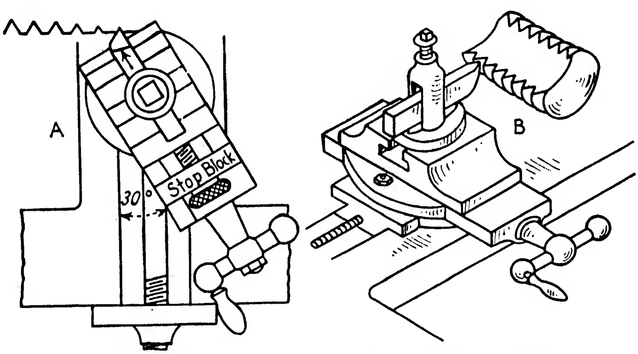


FIG. 69.—Using compound rest in thread cutting.

Toolmakers sometimes set the compound slide at angle to secure increased accuracy of tool feeling in for depth. If the slide is swung 60 deg., a reading of 0.001 in. on micrometer dial of feed screw only advances tool into the work one half this amount. This is again cut in half by swinging the slide 75½ deg.

The American Standard Thread.—The American Standard form of thread, (formerly known as the *Franklin Institute or Sellers*) is so called because it was designed by William Sellers, recommended by the Franklin Institute, and had been adopted by the United States Government. This thread has the same angles as the V, 60 deg., but has one-eighth of the depth taken off the top and bottom.

The depth of a V thread of 1 in. pitch is 0.86 inch and of the United States Standard 0.65 inch, while the flat at top and bottom is 0.125 in. To find the depth for any other thread, divide these

figures by the number of threads to the inch. To help in allowing for the thread when boring a die, or other piece with internal thread, Table V will be found useful. This also gives the width of the flat for the point of the thread tool, but it is fully as easy to measure this with a standard thread gage and there is much less chance of error. Simply grind the tool to fit the gage for whatever thread is to be cut, being sure it is an American Standard thread gage, and not a V.

Before cross-feed screws were provided with micrometer dials, stop blocks were a great convenience in thread cutting. While they are convenient, even with the micrometer dial, stop blocks

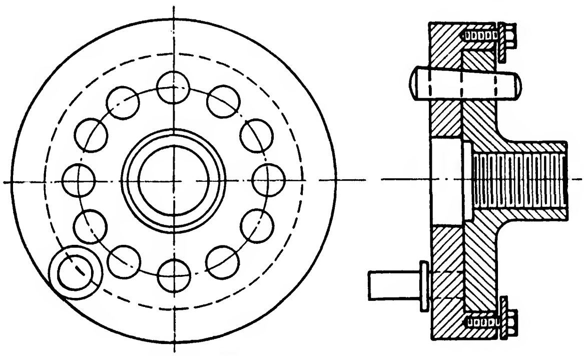


Fig. 70.—Indexing faceplate for multiple threads.

are no longer a necessity and the micrometer dials are very convenient in turning and boring, as in thread cutting.

Multiple Threads.—When a double thread is to be cut, the first thread is cut to one half the depth for that pitch and the second thread cut halfway between the grooves of the first thread. This space can be divided by measurement, by turning the work halfway round, or by turning the *stud gear* just halfway round. The last is probably the easiest except when an odd-tooth gear is on the stud. In that case it is probably easier to measure and move the carriage.

If there is much multiple-thread cutting to be done, the best way is to have an indexing faceplate made like that shown in Fig. 70.

This faceplate fixture can be used for various numbers of multiple threads. On an ordinary driving plate is fitted a plate having, as shown, 12 holes enabling one to get two, three, four,

TABLE V.—PROPORTIONS OF SCREW THREADS

Number of threads per inch	Lead of thread	Sharp V thread		U. S. standard thread		
		Single depth	Double depth	Single depth	Double depth	Width of flat
1	1.00000	0.8665	1.7330	0.6495	1.2990	0.1250
1⅛	0.88888	0.7702	1.5404	0.5773	1.1546	0.1111
1¼	0.80000	0.6932	1.3864	0.5196	1.0392	0.1000
1⅜	0.72727	0.6302	1.2603	0.4723	0.9447	0.0909
1½	0.66667	0.5776	1.1553	0.4330	0.8660	0.0833
1⅝	0.61538	0.5332	1.0664	0.3997	0.7994	0.0769
1¾	0.57142	0.4951	0.9902	0.3711	0.7422	0.0714
1⅞	0.53333	0.4621	0.9242	0.3464	0.6928	0.0666
2	0.50000	0.4332	0.8665	0.3247	0.6495	0.0625
2⅛	0.47058	0.4077	0.8155	0.3056	0.6113	0.0588
2¼	0.44444	0.3851	0.7702	0.2888	0.5773	0.0555
2⅜	0.42105	0.3648	0.7296	0.2734	0.5469	0.0526
2½	0.40000	0.3466	0.6932	0.2598	0.5196	0.0500
2⅝	0.38095	0.3301	0.6602	0.2474	0.4948	0.0476
2¾	0.36363	0.3151	0.6302	0.2361	0.4723	0.0454
2⅞	0.34782	0.3014	0.6028	0.2259	0.4518	0.0435
3	0.33333	0.2888	0.5776	0.2165	0.4330	0.0416
3¼	0.30769	0.2666	0.5332	0.1998	0.3997	0.0384
3½	0.28571	0.2475	0.4951	0.1855	0.3711	0.0357
3¾	0.26667	0.2311	0.4621	0.1732	0.3464	0.0333
4	0.25000	0.2166	0.4332	0.1623	0.3247	0.0312
4½	0.22222	0.1925	0.3851	0.1443	0.2886	0.0277
5	0.20000	0.1733	0.3466	0.1299	0.2598	0.0250
5½	0.181818	0.1575	0.3151	0.1180	0.2361	0.0227
6	0.166666	0.1444	0.2888	0.1082	0.2165	0.0208
7	0.142857	0.1237	0.2475	0.0927	0.1855	0.0182
8	0.125000	0.1083	0.2166	0.0812	0.1624	0.0156
9	0.111111	0.0962	0.1925	0.0721	0.1443	0.0138
10	0.100000	0.0866	0.1733	0.0649	0.1299	0.0125
11	0.090909	0.0787	0.1575	0.0590	0.1180	0.0113
11½	0.086956	0.0753	0.1507	0.0564	0.1129	0.0108
12	0.083333	0.0722	0.1444	0.0541	0.1082	0.0104
13	0.076923	0.0666	0.1333	0.0499	0.0999	0.0096
14	0.071428	0.0619	0.1237	0.0464	0.0927	0.0089
16	0.062500	0.0541	0.1083	0.0406	0.0812	0.0078
18	0.055555	0.0481	0.0962	0.0361	0.0712	0.0069
20	0.050000	0.0433	0.0866	0.0324	0.0649	0.0063
22	0.045454	0.0394	0.0787	0.0295	0.0590	0.0057
24	0.041666	0.0361	0.0721	0.0271	0.0541	0.0052
26	0.038461	0.0333	0.0666	0.0250	0.0499	0.0048
27	0.037037	0.0321	0.0642	0.0240	0.0481	0.0046
28	0.035714	0.0309	0.0618	0.0232	0.0463	0.0045
30	0.033333	0.0289	0.0577	0.0216	0.0433	0.0043
32	0.031250	0.0271	0.0541	0.0203	0.0405	0.0039
34	0.029411	0.0255	0.0510	0.0191	0.0382	0.0037
36	0.027777	0.0241	0.0481	0.0180	0.0360	0.0035
38	0.026315	0.0228	0.0456	0.0171	0.0342	0.0033
40	0.025000	0.0216	0.0433	0.0162	0.0324	0.0031
42	0.023809	0.0206	0.0412	0.0154	0.0309	0.0029
44	0.022727	0.0196	0.0393	0.0147	0.0295	0.0028
46	0.021739	0.0188	0.0376	0.0141	0.0282	0.0027
48	0.020833	0.0180	0.0360	0.0135	0.0270	0.0026
50	0.020000	0.0173	0.0346	0.0129	0.0259	0.0025
52	0.019231	0.0166	0.0333	0.0125	0.0249	0.0024
54	0.018518	0.0160	0.0320	0.0120	0.0240	0.0023
56	0.017857	0.0154	0.0309	0.0116	0.0232	0.0022
58	0.017241	0.0149	0.0298	0.0112	0.0224	0.0021
60	0.016666	0.0144	0.0288	0.0108	0.0216	0.0020
64	0.015625	0.0135	0.0271	0.0101	0.0202	0.0019
68	0.014705	0.0127	0.0254	0.0095	0.0191	0.0018
72	0.013888	0.0120	0.0241	0.0090	0.0180	0.00172
76	0.013157	0.0114	0.0228	0.0085	0.0170	0.00165
80	0.012500	0.0108	0.0216	0.0081	0.0162	0.00156
84	0.011904	0.0103	0.0206	0.0077	0.0154	0.00148
88	0.011363	0.0098	0.0196	0.0073	0.0147	0.00142
92	0.010869	0.0094	0.0188	0.0070	0.0141	0.00135
96	0.010416	0.0090	0.0180	0.0067	0.0135	0.00130
100	0.010000	0.0086	0.0173	0.0065	0.0129	0.00125

or six leads if required. A ring carries the driving stud, and is clamped at the back of the plate by two bolts as an extra safeguard. All that is necessary in operation is to slack off the bolts, withdraw the index pin, move the plate the number of holes required, and re-tighten the bolts. It can be used on different lathes, as occasion requires, by making the driving plates alike and drilling a hole for the index pin. It is found that the index pin works best when made taper, so that a light tap is sufficient to loosen or fix it.

With this index plate one thread is cut to its full depth, or a partial depth if you prefer to leave a finishing cut to be taken after they are all roughed out, then pull the index pin and turn to the right point. There are fewer chances of springing a bar if the threads are partially cut in each place and then light finishing cuts are taken in all the threads.

Dimensions of Screw Threads.—While the table almost explains itself, an illustration may help a little. Let it be required to make a special nut, 1 in. diameter, 12 threads per inch American Standard. From Table V we find the double depth of thread to be 0.1082 in., which, subtracted from 1 in., leaves 0.8918 in., the required diameter of bore.

Or, if we wish to know how far a nut will advance for one turn of a screw having $1\frac{5}{8}$ threads per inch, we find this from the column marked lead, opposite the number of threads per inch, to be 0.61538 in.

TABLE VI.—SQUARE-THREAD TOOLS—WIDTH AND DEPTH OF THREADS ARE THE SAME

	Width of thread tool		
Pitch or threads per inch	Single thread	Double thread	Triple thread
1	0.5	0.25	0.166
2	0.25	0.125	0.083
3	0.166	0.083	0.055
4	0.125	0.062	0.042
5	0.10	0.05	0.033
6	0.083	0.042	0.028
7	0.071	0.035	0.023
8	0.062	0.031	0.021

Square Threads.—Square threads are difficult both in grinding the tools and in cutting the thread. They are not used where Acme or other forms with angular sides will answer. The width of the tool is half the pitch plus whatever clearance is thought necessary. In *A*, Fig. 71, a pitch of 1 to the inch is shown. This means either the distance from center to center of threads or from the face of one thread to the corresponding face in the next thread.

If it is a double or triple thread, we must be careful and not confuse pitch and lead. The depth of the square thread is usually the same as the width of the land or the space, plus an

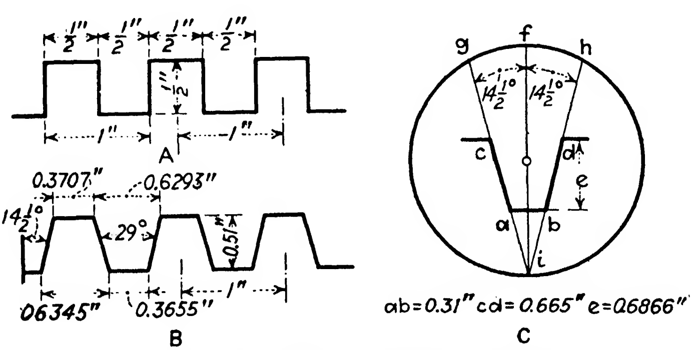


FIG. 71.—Square, Acme and worm-thread forms.

allowance for clearance at the bottom. The square thread is rather difficult to cut on account of giving clearance on the sides of the tool, owing to the angularity of the thread.

In cutting double threads of square section, the same precautions must be observed as with V or other threads. Table VI gives the theoretical width of square-thread tools for use in cutting single, double, and triple threads. Clearance should be added in each case.

Acme Threads.—Owing to the difficulty of cutting square threads many screws were made flat top and bottom, but with sloping sides of any angle that pleased the eye of the man who ground the thread tool. As these were neither square nor V, they soon had a name of their own and were called bastard. In some parts of the country this term is applied only to odd pitches, but any old lathe hand will recall bastard threads of a great variety of shapes and sizes. No two of these were alike, and the natural

course of events brought about a standard which is now known as the Acme thread. The proportions for a pitch of one to the inch are shown in *B* (Fig. 71), and Table VII gives full details for other sizes.

TABLE VII.—PROPORTIONS OF ACME THREADS

No. threads per inch, linear	Depth of thread	Width at top of thread	Space at bottom of thread	Space at top of thread	Thickness at root of thread
1	0.5100	0.3707	0.3655	0.6203	0.6345
2	0.2600	0.1853	0.1801	0.3147	0.3199
3	0.1767	0.1235	0.1183	0.2098	0.2150
4	0.1350	0.0927	0.0875	0.1573	0.1625
5	0.1100	0.0741	0.0689	0.1259	0.1311
6	0.0933	0.0618	0.0566	0.1049	0.1101
7	0.0814	0.0529	0.0478	0.0899	0.0951
8	0.0725	0.0463	0.0411	0.0787	0.0839
9	0.0655	0.0413	0.0361	0.0699	0.0751
10	0.0600	0.0371	0.0319	0.0629	0.0681

TABLE VIII.—BROWN AND SHARPE WORM-THREAD PROPORTIONS

Worm threads						
Pitch in threads per inch	Lead per revolution	Depth of thread	Width of tool point or bottom of thread	Width at top of thread	Width of space at top of thread	Width of root of thread
1	1	0.6866	0.31	0.335	0.665	0.69
2	0.5	0.3433	0.155	0.167	0.332	0.345
3	0.333	0.2288	0.103	0.111	0.222	0.23
4	0.25	0.1716	0.077	0.084	0.166	0.17
5	0.20	0.1373	0.06	0.067	0.133	0.14
6	0.166	0.1144	0.05	0.056	0.111	0.115
7	0.141	0.0981	0.044	0.048	0.095	0.098
8	0.125	0.0858	0.039	0.042	0.085	0.086

Worm Threads.—The Acme thread is so near the worm thread that care must be taken to avoid using one for the other or getting the proportions mixed. The angle is the same, 29 deg.; but the depth of the worm thread is greater, as can be seen in *C* (Fig. 71). This also shows an easy way to lay out the angle of 29 deg.

Draw a circle of 2 in. or any other diameter; draw a line through the center, as *fi*. Take one-quarter the diameter, or ½ in., in the dividers and mark off *g* and *h* from *f*. Connect *gi* and *hi* and the enclosed angle is 29 deg. This is probably why 29 deg. was selected.

The point of the tool *ab* is 0.31 × the pitch: the space *cd* is 0.665 × the pitch; and the height *e* is 0.6866 × the pitch, according to the Brown & Sharpe standard, or practically one-third deeper than the Acme thread. The details are given in Table VIII.

Chasers and Special Tools.—A chaser, as known to the engine-lathe man, is a thread tool with several points, as shown in Fig. 72;

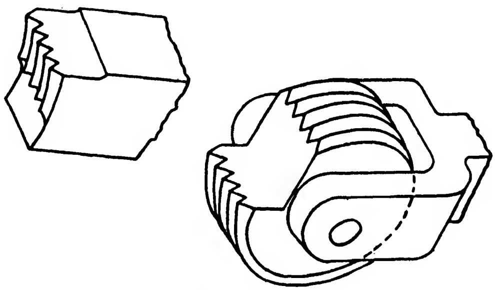


FIG. 72.—Two forms of thread chasing tools.

when used, it is generally kept for finishing threads and not for roughing. The old chaser was like the one at the left, being a straight tool with threads cut in the end like a die chaser and was cut with a hob. The other is a later development and though usually confined to screw machines, it is sometimes used in the engine lathe. It is made by cutting a thread of the desired pitch on a steel roll, milling out a flute and clamping the roll so as to bring the cutting edge at the right position on the work. It can be sharpened by grinding the face and will last until most of the roll has been ground away. Chasers are well thought of by many for finishing long threads. One holder will handle rolls for different pitches of threads.

There is a great difference of opinion as to the best lubricant for use in chasing threads. Nearly every machinist has his pet screw-cutting oil, which includes fish oils, heavy crude oils, emulsions of soap, oil, and water, soda water with variations. Cutting lubricants are discussed in another section.

Cutting Quick Pitch or Fast Threads.—Quick pitch or fast threads present difficulties when only the usual equipment is available. The power required to feed the threading tool ahead at a sharp angle is often beyond the capacity of the lathe which is otherwise strong enough for the work. The gear train and the

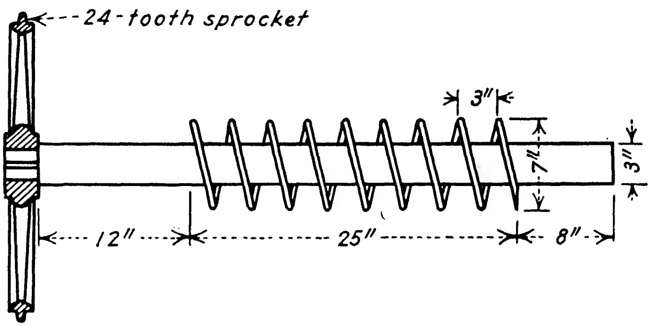


Fig. 73.—The wrong way to cut a fast thread.

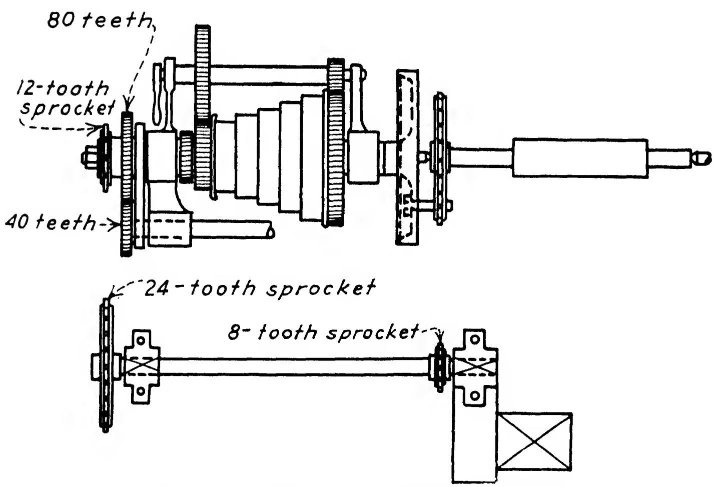


Fig. 74.—This method worked successfully.

parts between the lathe spindle and the lead screw are not designed for such work.

One method of handling such a job is illustrated in Fig. 73, showing an outline of the screw to be cut and the sprocket which was fastened to it to drive it. The screw was 7 in. outside diam-

eter and had a 3-in. lead. The threads were ⅜ in. wide and 2 in. deep, which added to the difficulty. The lathe was old and geared a 12-to-1 ratio, the lead screw being ¼ in. pitch, or 4 to the inch. After wrecking the gearing trying to cut the thread in the regular way, the method shown in Fig. 74 was tried, successfully.

With this combination the lathe drives the countershaft which in turn drives a quill on the compounding stud of the quadrant. This quill carries an 80-tooth gear which drives the 40-tooth gear on the lead screw through an intermediate gear. This method worked well as the sprockets secured the proper ratio between the work and the lead screw. The sprocket on work has 24 teeth.

A Tool for Threading Slender Work.—The tool, Fig. 75, is helpful in threading slender work. A mandrel was to be cut for

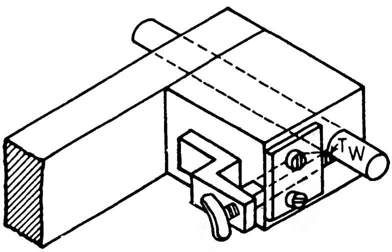


Fig. 75.—Thread tool for slender work.

winding springs of No. 20 spring-brass wire and the thread to be cut was 14 in. long, 5 per inch and left-handed.

The outside diameter of arbor was 0.345 in., the bottom of thread 0.310 in., and it had to be perfectly straight. The whole length of arbor was 18 in. A guide was made out of 2-in. square steel with a hole drilled through it the size of arbor ends, and fastened to a shank to fit the tool post. A place for a thread tool was planed in the block, this tool being adjusted in and out by a screw, as shown. The actual thread cutting was quite easy, as the tool held the work from springing while being threaded.

Threading Fiber.—In threading fiber it has been found that a tool with a top rake as used on metals will tear the material. A negative rake should be used, the angle being determined to some extent by experiment.

Ordinary medium-grade cup grease, applied by hand is a satisfactory lubricant for thread cutting. Vaseline or any form of petrolatum will also answer.

Cutting Internal Threads in Tough Metals.—In experimental work it is often necessary to cut internal threads in copper, nickel, or other tough metals, and it is almost impossible to produce smooth work with a single-pointed tool. In the illustration (which is a plan view) is shown a quick and easy method of doing such work satisfactorily.

The cutting is done by a tap of the desired pitch, as in Fig. 76, but smaller in diameter than the hole in which the threads are to be cut. With the work mounted in the lathe chuck in the usual manner, the tap is held in a drill chuck, the straight arbor of which is clamped in a holder for small boring tools, the holder being held in the tool post of the lathe.

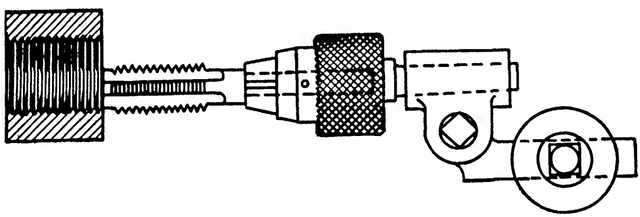


Fig. 76.—Chasing threads with a tap.

It will be understood that the cutting edge of one of the tap lands is set at the center line of the work and that the tap does not revolve but is used as a chaser. Taps on which the first few threads have been broken may be ground to suitable shape and kept for such work.

Testing the Lead Screw of a Lathe.—The accuracy of the lead screw is very seldom considered in buying a lathe unless it is bought especially for screw-cutting purposes. The screw can be easily tested on its own lathe to see what results it will produce. Having a large faceplate on the lathe, take a surface gage, set it on a parallel across the ways and scribe a line on the edge. Run the carriage back as far as possible. On the ways behind the carriage clamp a small block of cast iron *A*, Fig. 77, in which is inserted a micrometer barrel, as shown in the sketch. On the carriage is a block *B* with a pin in the end the same diameter as the micrometer spindle. A 6-in. distance rod is also needed. Engage the half-nut. Gear for 4 pitch, then one revolution of the spindle will make the carriage travel ¼ in.

Turn the faceplate *D* one revolution until the line is even with the needle of the surface gage *C*. Set the micrometer barrel at zero against the carriage. Turn the faceplate 24 revolutions, try the 6-in. distance rod and see whether the distance is short, long, or correct. Move the micrometer-barrel block up to the carriage and again set at zero; turn the lathe 24 revolutions more and test again. It is probably best to test the screw every 6 in., as this will be near enough for ordinary screw cutting.

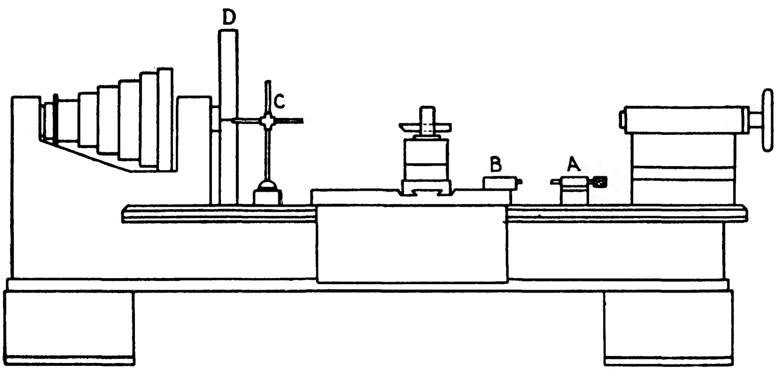


FIG. 77.—Checking accuracy of lathe lead screw.

HANDY LATHE KINKS

Using Indicators.—Whether for testing the concentricity or straightness of a mandrel, the run-out of a faceplate, or the location of work on the faceplate, a good indicator is of great assistance.

Perhaps the simplest example of using an old-type indicator in a lathe is for locating a piece of work on the faceplate or in a chuck. For ordinary work, where the limit of accuracy may not be closer than $1/32$ in., the indicator is hardly necessary as you can locate the prick-punch mark or the hole, either by the eye or with the point of a lathe tool. But for really nice work the indicator is a fine tool, even in its cruder forms as shown in Fig. 78, which is one of many types in general use.

This is simply a piece of steel, *A*, pointed at both ends and having the steel wire *B* fastened in a crosswise hole, with the long end bent down so as to be in line with the centers of *A*. It will be readily seen that as the arm *B* is much longer than the piece

A, the end of the pointer will multiply the distance the point *C* is out of center when the work is revolved.

When the point *C* is exactly central, the point *E* will remain stationary; but if the point *C* is out of center one-hundredth of an inch, the point *E* will travel in a circle having a radius as many times this as the distance from *C* to *E* is longer than from *C* to *A*.

To use this, a punch mark is made on the side of a lathe-tool shank and this fastened in the tool post so that the punch mark

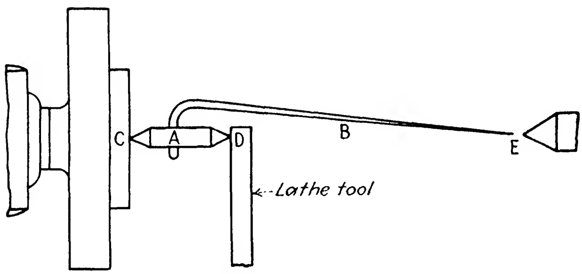


FIG. 78.—Simple form of lathe indicator.

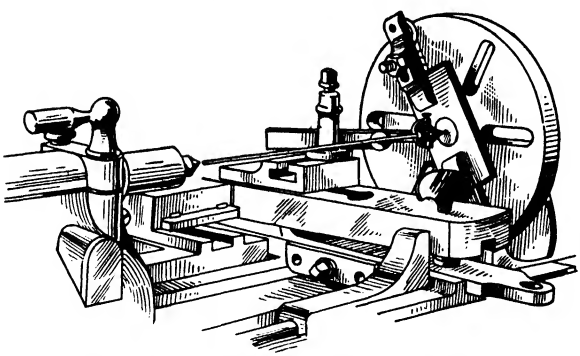


FIG. 79.—A better indicator of similar type.

comes as near the center of the lathe as possible. Then the point *D* is placed in the punch mark, the point *C* on the work and the work revolved, usually by hand. Watching the point *E* tells the story whether it is sighted by the dead-lathe center or not. When the end of the pointer stands perfectly still while the work is being turned, the center of the work is located at the exact center of the lathe.

Other examples of using indicators of different kinds in centering work are illustrated in Figs. 79 to 85. These show indicators

made by Starrett and by Brown and Sharpe. Figure 79 is a more convenient form of Fig. 78. Figures 80 and 81 show a

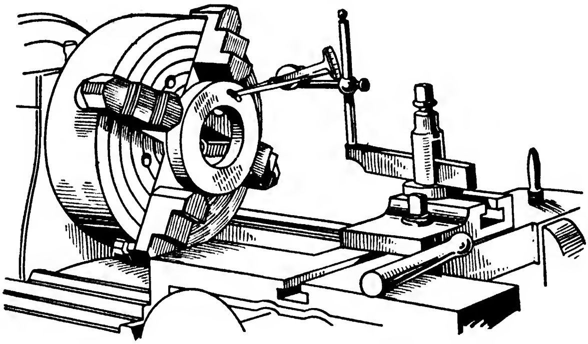


FIG. 80.—Another type of multiplying indicator.

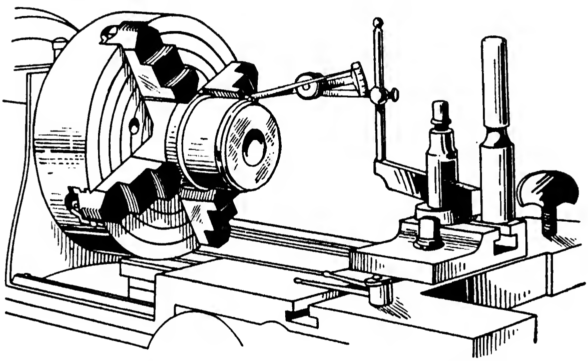


FIG. 81.—Same indicator used on outside diameter.

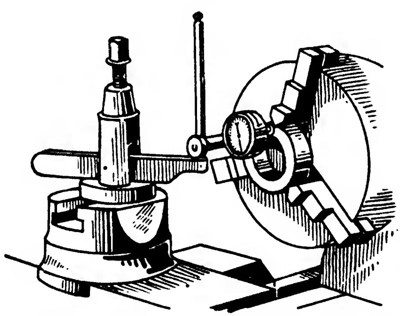


FIG. 82.—Dial indicator used on face of work.

convenient type of indicator testing the face and outside diameters, respectively. When the work is revolved slowly, any

variation is greatly multiplied on the indicator scale. In Fig. 82 a dial-type indicator is being used on the face as in Fig. 80. Still another type of dial gage is shown in Fig. 83, checking the concentricity of the bore. This is reversed in Fig. 84 where the indicator is clamped to the spindle to check the alignment of the stud in the angle plate with the lathe spindle. Still another method of testing concentricity is shown in Fig. 85. Here a surface gage with a V groove as the base, is placed on a bar that is true with the lathe spindle. By testing in various positions around the circumference, the ring can be trued with the bar. This method is neither as convenient nor as accurate as those shown previously.

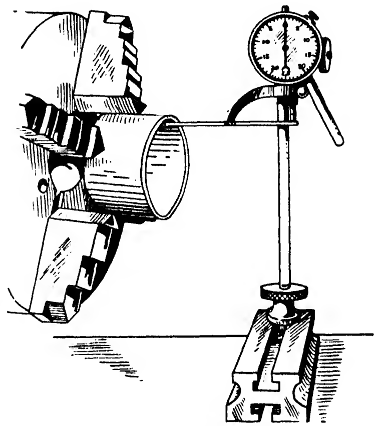


FIG. 83.—Still another multiplying or amplifying indicator with dial readings.

Finishing up Work.—In the various operations of machining, fitting, and assembling of machinery and tools, too often details in method and finish are overlooked, resulting in a finished article which is defective in operation and unsightly to the truly mechanical trained eye.

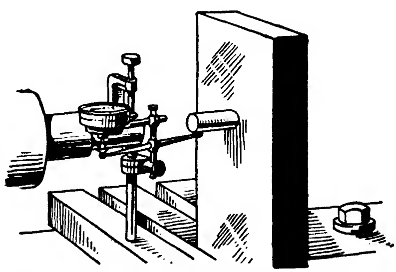


FIG. 84.—Another use for the same indicator.

Were the little omissions referred to confined to the novice, it would be hardly worth while to mention them, but experience has proved that the middle-aged journeyman is sometimes as great a sinner in this respect as the apprentice. It sometimes happens

that those placed in charge, through lack of shop training, are not able to see small defects or judge their importance.

Notice the first thread on the screw shown at *C*, Fig. 86. This is the way many so-called lathe hands turn the job over to the bench hand to finish with a file.

After the thread has been cut to size, before removing the tool or work from the lathe, open the lead-screw nut, move the carriage by hand and chamfer as shown at *B*, leaving it finished as shown at *A*. This not only looks better but is better, and takes less time. The same method applies to the threading of a nut on the lathe. The above does not apply to harvesting machinery, but to tool work where accuracy usually is economy.

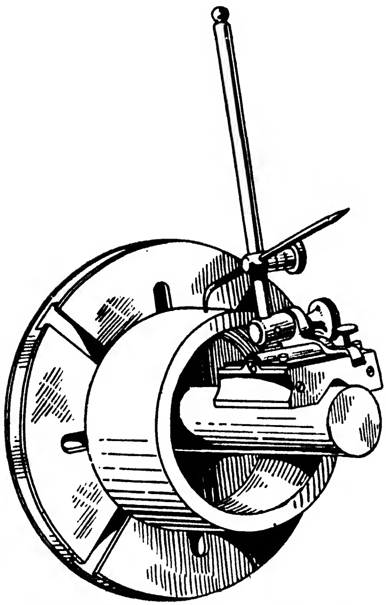


FIG. 85.—Checking concentricity with a surface gage.

There is no excuse for leaving center projections on the ends as at *D*. They can be easily faced off by backing the tailstock center a little, and a facing tool fed in as at *E*.

By looking at *E*, Fig. 86, it is apparent that 55 deg. is about the proper angle to grind a facing tool. This gives ample strength and permits facing close to the center without interfering.

Drilling Kinks.—Any one who has ever drilled a hole in a lathe by holding the drill with a dog, and feeding it in to the work with the tail spindle, has probably had the drill catch just as it broke through the work, draw off the center, and possibly break the drill.

To prevent this, especially in brass work, it is customary to grind the lips of the drill so that they have no top rake, or what corresponds to that in a lathe tool, but there is a better way, even without the use of a drill chuck of any kind.

Put a piece of steel or a lathe tool into the tail post, backward, as is often done, but, instead of letting the dog rest on the top of

the tool, have it rest on the tool holder and back up against the tool, as shown in Fig. 87. This pulls the carriage along as the

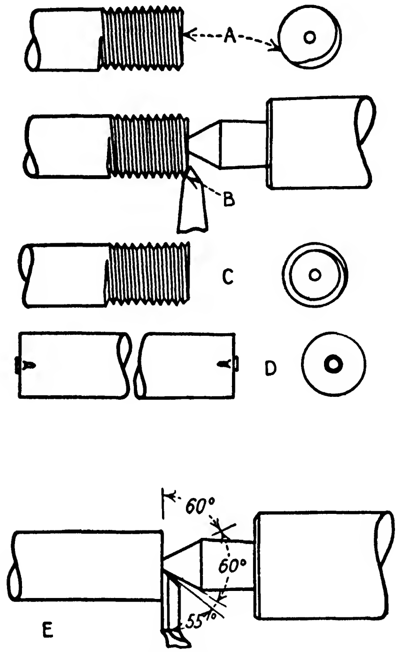


FIG. 86.—Finishing the ends of work.

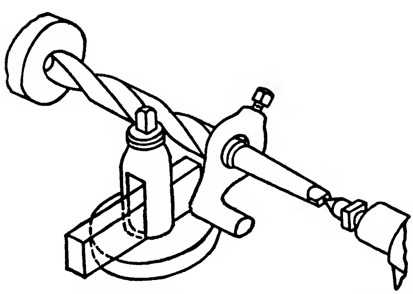


FIG. 87.—Guarding against drill breakage.

drill is fed into the work, and it effectually prevents any dragging of the drill into the work with the damage that often goes with it.

Three Types of Centering Mandrel.—The use of mandrels in order to have the last turning operations come true with the hole

previously bored has changed somewhat in the last few years. Where a piece cannot be finished at one setting, as a blank for a change gear or similar work, it is customary first to bore the hole and face the hub. Then, in the old days, it would have been forced into a mandrel which was made a very slight taper, from 0.001 to 0.002 in. per inch of length; the mandrel driven between the lathe centers and the work turned off. If the mandrel is true, the piece will then be finished square and true with the hole.

All who have done this know of the occasional slipping of the piece through the cut being too heavy or the mandrel a trifle too small. They also know of the old way of enlarging the mandrel by prick-punching it to raise burrs all over it. If the work is not particular, it can be driven on over the burrs and will hold, though it will not be quite true. Or it can be ground after prick-punching and trued up again.

The solid mandrels took tons of steel and iron as each was good for only one size, and the expansion arbor became common on account of the saving in stock and the fact that they could be varied within reasonable limits to fit any size.

When the hole is small in comparison with the outside diameter, it is often difficult to drive work in this way and the work slipping or the mandrel bending is a common occurrence. For this reason, as well as to facilitate the handling of work, the centering instead of the driving mandrel has come into use. Forcing a mandrel into the work takes time and this is avoided in the newer method. This means that the mandrel merely centers the work but does not drive it as shown in *A*, Fig. 88.

In such cases the mandrel might be called a stud or pin and is carried in the lathe spindle, projecting just far enough to carry the work, but usually not projecting through the hub. The piece is usually first chucked and bored and the face turned off at the same setting. Then, after the pieces are all bored, the centering mandrel is put in place, the faceplate and stud screwed on, and the lathe is ready.

If the mandrel runs true, the faceplate is square, and the parts kept clean, the work will run true with the hole. The blank is slipped on the mandrel so that the stud will come between the spokes or in the holes and drive the gear. Then a cap or center plug, as shown, is pushed into the outer end of the bore to hold the work square and keep it in place, this being removed when the

outer hub is squared. Or the hub is squared first and then the plug put into place. This is not necessary in all cases as the pressure of the facing tool will tend to keep the work against the faceplate on cast-iron work. On steel castings or metal that rolls up a chip, there is more danger of the work being pulled off the mandrel and something must be done to prevent it.

In some shops the centering arbor is fitted with a key *B* and the work is driven in this way. This necessitates key-seating or

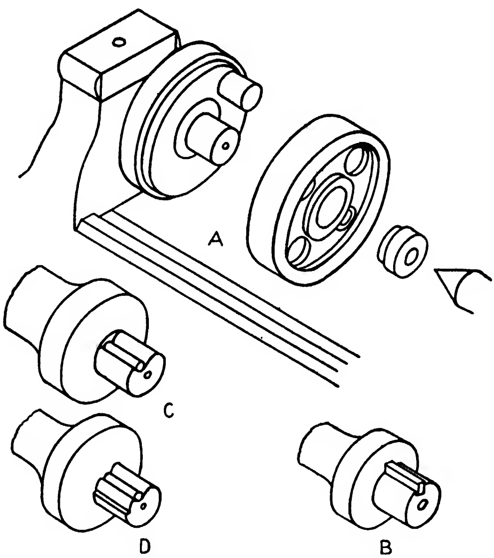


FIG. 88.—Work centering and driving mandrels.

splining the work after boring, but in a shop with a key seater this is easily and quickly done. It is, of course, not advisable to use this method with work that is large as compared with the hole, it being always better to drive the work as near the cut as possible. This plan is used whether the work needs to be key-seated or not, for, as a rule, the key seat does no harm whether it is needed or not.

In work where the key seat is objectionable or where there is no key-seater handy, the device shown in *C* is sometimes used. The mandrel fits and centers the work as before, but as the tool tries to turn the work on the arbor, the roller tends to roll up the incline, as in a roller ratchet, and holds the work from turning. There is always the tendency to crowd the work off center with

this device, much more so than where the key is used, and it may be objectionable on this account in very accurate work.

This is modified in some cases by making the work bear only on the lower half of the arbor as in *D*, and cutting away the upper half, allowing the roller to bite as before, so that it draws the bore of the work up against the mandrel. In this way the bearing part of the mandrel can be exactly to size instead of having a slight allowance for the work being slipped on.

In all of these the object is to hold the work accurately and securely, to drive it steadily, and allow it to be put on and taken off easily and quickly.

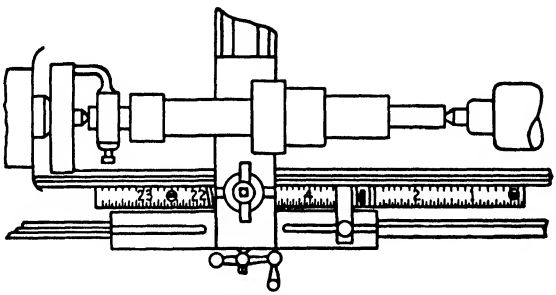


FIG. 89.—Direct measurement of shoulders.

With the mandrel best adapted for the work in hand, and face-plates that allow the work to be held and driven, yet faced down on the back side, a large variety of duplicate work can be done on the engine lathe at a low cost, much lower than is usually considered possible. A fork tool can go down each side of the rim and face it to size, while a regular tool turns the outside diameter. Suitable stops allow the tools to be moved to the same place every time and in this way do away with much measuring, as they will all be alike except for the wear of tools.

Direct Length Measurement of Lathe Work.—A method of measuring the total length of lathe work, as well as the distances between shoulders, so that further measuring will not be necessary after the work has been completed, is indicated in Fig. 89.

A scale of sufficient length is attached by screws to the lathe bed between the V's, and an adjustable gage is attached to one wing of the carriage. By setting the gage to some predetermined starting point on the scale, the carriage and, of course, the

tool can be moved longitudinally a definite distance, depending for closeness on the graduations of the scale.

Milling in the Lathe.—In small shops that have no milling machine, the attachment illustrated in Fig. 90 can be made for use in the lathe. As shown, it is used for milling squares on the ends of shafts, but other simple jobs can be done as well. Indexing is done by rotating the work 90 deg., using a square for the setting.

The compound rest is attached to an angle plate mounted on the tool block by screws and dowels, and the vise is attached to

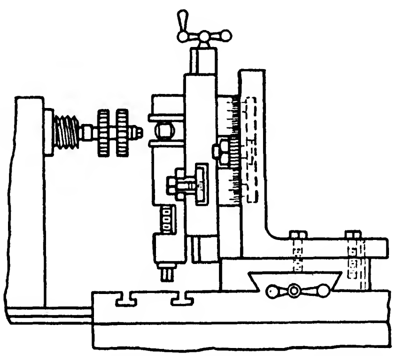


Fig. 90.—Milling attachment for lathe.

the compound rest as shown. As the distance through the ears of the vise is greater than the width of the compound rest, a piece of flat bar stock of the proper length is put in the tool-post slot of the compound rest, the ends projecting far enough to receive the bolts put through the ears of the vise.

Vertical and horizontal feeds are provided by the compound rest and the regular cross feed of the lathe. If a circular slot for the bolts of the compound rest is machined in the vertical face of the angle plate, the compound rest can be set at any desired angle.

Care of the Lathe.—Lathes and other shop tools deserve more care than they usually receive. This does not mean that it is necessary to polish every part of the lathe, and scour it bright with abrasives. In fact these should be used sparingly. If the lathe has been allowed to get "gummy" from the oil not being wiped off, use a little kerosene or benzine.

When you see a lathe with the ways dented and scored and other parts in a similar condition, it is safe to say the man in charge is not a high-grade machinist. Even if he is not responsible for the condition, he will endeavor to remedy it as quickly as possible, even in his own time, if no other is allowed him. Character shows up just as strongly in the shop as elsewhere, and unless a man or boy thinks enough of the tools he uses to take decent care of them, and has enough interest to do this, it is fairly safe to say he will never be a first-class machinist. If it is the right kind of a shop, the care of the tools will be noted by the man higher up, and it counts when a better job comes along.

A little oil and frequent use of it is the best with lathes and other machinery. The spindle bearings should be tight enough to prevent lifting or jumping and require oil to prevent heating and cutting. Lathes with cast-iron bearings must be watched closely. Cast iron makes a fine bearing after it gets glazed, but it must not be allowed to run dry. Some careful machinists fill the top of the oil pipe (or bottom of the oil cup if there is one) with clean waste, to keep dust and chips from being washed down to the bearing with the oil. Lathes with antifriction bearings should be lubricated carefully according to the instructions of the builder. Too much oil is not good for them.

Keeping the ways lubricated is not easy, as the angle lets the oil run down, and it also attracts dust and dirt for the carriage to run over. The plan adapted by some of the best shops is to wipe the ways clean each morning, put on a few drops of oil, and run the carriage from one end to the other, so as to work the oil under it. Any surplus is wiped off to prevent its running down and gumming. Some lathes have felt oiling pads.

The various bearings on the apron of the carriage should all have their little drop of oil, through the hole provided in the front of the apron. Some now have oiling pumps. The back gears, the bearings of the feed rod, and the lead screw all deserve a little attention, as well as the screws and bearings of the cross feeds and the tailstock. The dead center also needs a drop of oil occasionally, especially on heavy work. To assist in this, heavy centers are often provided with an oil groove on top for feeding the oil to the bearing. Some prefer to cut an oil groove in the center of the work itself, so that it will carry the oil around with it, but this is not usually considered advisable.

The piling of work, tools, and other things on the lathe-bed and on the carriage is not a good plan. It marks up the bed, gets in the way of the carriage at times, and is usually more of a bad habit than a necessity. While it is not a criminal offense, the habit should not be encouraged.

When it is necessary to have work or special tools around, they can usually be kept on the tool board at the foot of the bed. This tool board should have the sides raised enough to prevent the tools from falling or being pushed off, and it can be double-decked if more room is needed. Two strips underneath, to fit the inside of the ways, prevent its being accidentally pushed off the end.

The center holes in the lathe spindles require especially good care, as the center will be thrown out of true if anything, even a thread of waste, is left in the hole or on the center hole. Even the "fuzz" from waste affects it on fine work, and for this reason some of the best mechanics use a small brush or cloth instead of waste, for this purpose. When it is not being used, it is a good plan to insert a cork or a blank center to prevent dirt from entering.

The threads on the nose of the spindle should also be well cared for. One trouble that arises is the "crossing" of threads in putting on chucks and faceplates. This can be avoided by being sure that the chuck or faceplate is held square with the spindle when putting it on. When no chuck or faceplate is on the spindle, some protect the nose by screwing on a cap or slipping one of sheet metal over it.

The centers themselves also demand good treatment if first-class work is to be done. They must not be dropped or used for hammers or center punches.

Overhang of any part is always bad, though it cannot always be avoided. The lathe tool, the tail spindle, and the compound rest are all to be watched in this respect.

Perhaps the most common abuse of a lathe or its parts is the practice of using the tool-post wrench for a hammer to force the lathe tool into position. Even men who are careful of the working parts of a lathe will do this at times, and it may be a trifle finicky to object to it. But it is just as well to avoid it before the habit is too firmly fixed.

*The weekly cleaning of lathes, usually the last half or quarter-*hour of the week, is a good thing in many ways for most shops. In sonfe cases it may pay to have special men to clean them after hours, but the mechanic is better fitted for this than a laborer unless the latter is especially trained for the work. The cleaning process, however, should not be turned into a scouring match, as sometimes happens. A clean lathe doesn't necessarily dazzle your eyes, but has the gum and dirt carefully wiped off.

THREAD ROLLING

Forming threads by rolling is an old idea, having originated in England over 100 years ago. In this process the blank is made of

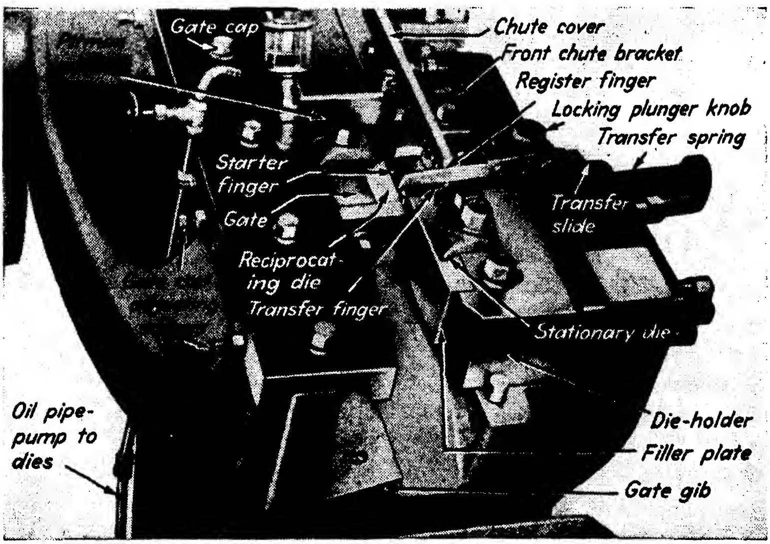


Fig. 91.—Flat-die thread roller of the Rolled Thread Die Company.

practically the pitch diameter of the thread. The threading tools force the metal below the pitch line to flow up into the spaces and bring the outside diameter up to size. The earlier thread-rolling tools were round and were used on such rough work as track bolts. These soon gave way to the flat threading dies which are commonly used in threading all sorts of machine small screws and bolts, and have been used in rolling precision threads, sometimes finishing threads that had been rough cut with a die.

Now the use of round threading dies is gaining ground, and

there are several types of thread-rolling machines using dies of this type. The two types shown in Figs. 91 and 92 are made by the Rolled Thread Die Company of Worcester, Mass.

The section of the flat-die machine has the principal parts named which helps in following the action of the machine in producing the rolled thread. As will be seen, one die is stationary while the reciprocating die is moved past it by a ram. This carries the screw blank between the two dies and forms the thread

Fig. 92.—A new round-die machine by the Rolled Thread Die Company.

while it is being rolled between the two dies. The threaded screw drops out of the way when it reaches the end of the stationary die and falls into a suitable receptacle. The blanks are fed into the machine under the chute cover shown at the right.

Thread rolling is really a cold-forging process and forms the fibers of the metal instead of cutting them. This cold working increases the tensile strength of the part and also gives a very good finish to the surface. With proper dies and operation of the machines, rolled threads can be made extremely accurate.

Up to the present, thread rolling is confined to external threads but it is quite possible that the process can be adapted to forming threads inside of tubing or other hollow bodies, but it is never likely to replace what we now consider the tapping process. It is essentially a process adapted to high production and is not adapted to making screws in small quantities. It is necessary to have the blank of correct diameter to produce screws that are satisfactory as to size. Where the blank is cut from a rod of stock, the screw diameter will be larger than the body of the bolt. Where this is objectionable the portion to be threaded can be machined or rolled to the proper diameter before the thread is made.

Successful thread rolling is usually confined to thread forms having fairly steep angular sides rather than Acme or similar thread forms. Threads of from 60- to 47½-deg. angles are easily rolled. These include the American National, the Whitworth, and the British Association threads. Success depends primarily on selecting proper equipment as to the machine, the right dies for the work, and correct preparation of the blanks to be rolled.

Thread-rolling machines with round dies are now being used to a considerable extent, with several designs available. The machine shown in Fig. 92 has three rollers and is made by the Rolled Thread Die Company. The closing of the thread rollers on the work is controlled by the cam which moves the connection with the outer ring shown. Suitable adjustments make it possible to handle quite a range of screw diameters in such a machine. This makes a very compact form of machine and is preferred by some for several classes of work. It will handle a wider range of work than the flat-die machine.

Die life with either type of machine depends largely on the care used in its operation. Proper adjustment of dies and the selection of stock that is not too hard are both important. On material as hard as Rockwell C-35 it is difficult to maintain smooth cuts, and die life is short. Screw threads are now being ground from the solid with remarkable speed and accuracy. Details of this method will be found in "Grinding Practice."

CHAPTER VI

FUNDAMENTALS OF ACCURACY WITH V BLOCK, MANDREL, ARBOR AND SURFACE PLATE

These fixtures were developed by G. M. Evans, manager of the Kelvinator Company, to secure extreme accuracy by simple methods, using an engine lathe with comparatively simple fixtures. All fixtures, for both machining and inspection,

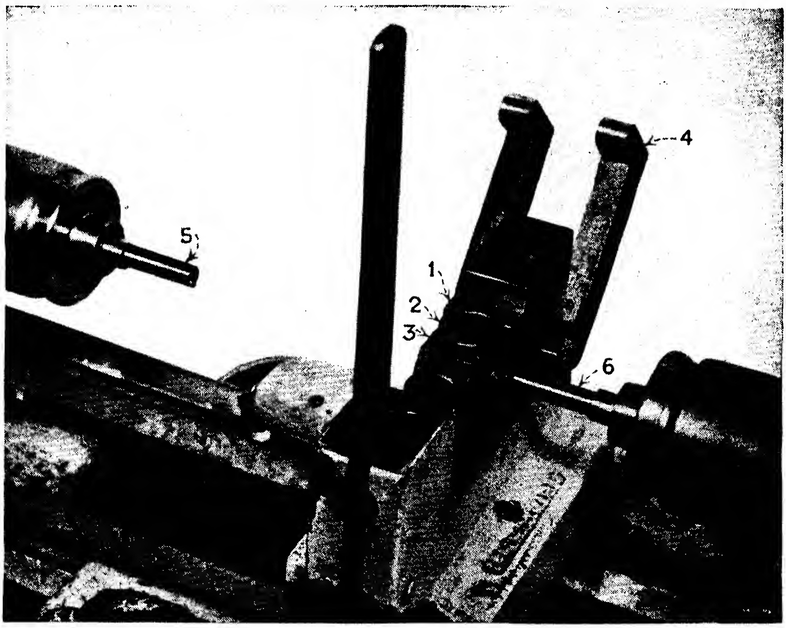


FIG. 93.—Boring pinhole in piston.

are based on the V block, the mandrel, and surface plate. The simplicity of the fixtures makes it possible for the semiskilled man to use them on standard machines.

Boring the pinhole in the piston (Fig. 93) finishes it within a tolerance of 0.0002 in. between the Go and No-go gages. The

work is done on the bed of a standard lathe fitted with a boring head at each end. The V block, 1, locates the piston, 2, which is held by the close-fitting clamp 3. The height is fixed by a stop under the piston. A loose-fitting mandrel is put through the rough-bored hole and the two aligning fingers, 4, are swung down in contact with the arbor. This lines the hole in the piston

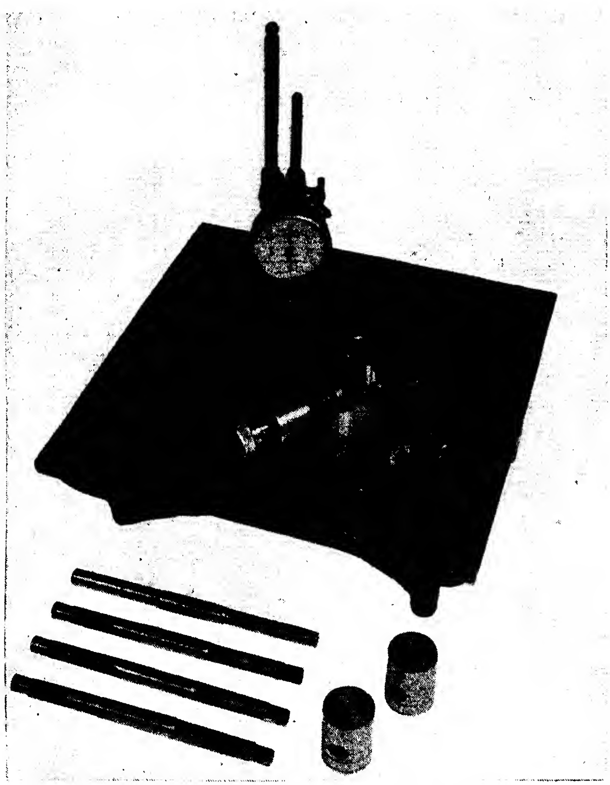


FIG. 94.—Checking squareness of hole.

true with the ways of the lathe. The fixture is mounted on the saddle of the lathe carriage. A spring holds jaw 3 in place. It is released by the handle as shown.

With the piston locked in place, the first cut is taken with the single-point cutter 5, and the bore finished by cutter 6.

Checking Squareness.—The method of checking the squareness of the hole is seen in Fig. 94 where the piston is again held

in a V block that is square with the surface plate and the mandrel through the hole is measured, from the surface plate, by the dial indicator shown. The mandrel is 7 in. long and the indicator is read to tenths of thousandths. This type of inspection fixture is easily made, checked, and replaced.

In boring the connecting rods, the V blocks gave way to the angle plate, as shown in Fig. 95, because the outside of the rod was not finished. Clamp 1 holds the under side of the rod against a knife edge by means of a ball on the end. The other clamp, 2, holds the small end of the rod against a single ball

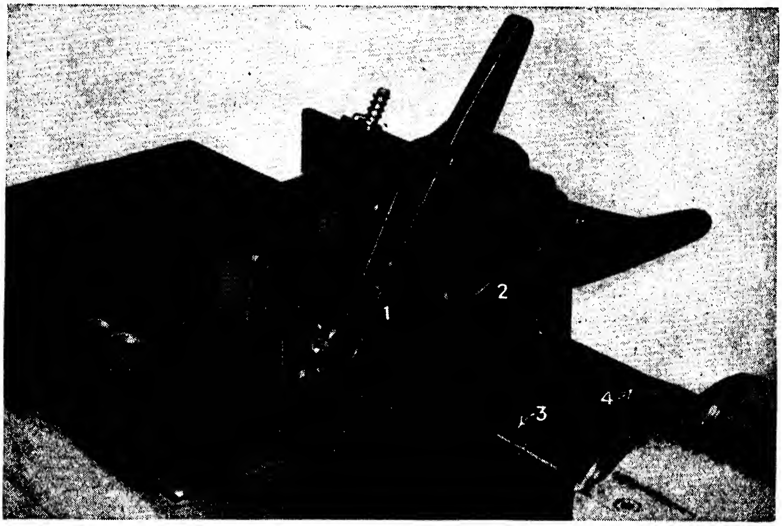


FIG. 95.—Boring connecting rods.

point, making a three-point bearing and preventing distortion of the rod from clamping. Both clamps fit closely in guides. These guides prevent side movement of the clamps as this might tend to move the work in clamping. The two boring bars are set at the correct center distance and parallel. The rod is positioned by the small V edges on blocks which fit in shallow notches in the bolt bosses on the rod.

Boring Holes in Parallel.—These holes must be parallel in both directions, within 0.0001 in. in 12 in. This is checked on a surface plate with mandrels and V blocks, as in Fig. 96. With the rod held vertically as at 1, the parallelism can be checked

by reversing the rod and mandrels. Repeating this with the rod horizontal, as at 2, "wind," or parallelism at right angles, can be checked.

The two cylinder bores (Fig. 97) must be parallel within one tenth in 12 in., and square with the crankshaft hole. A mandrel, 2, is wrung into the crankshaft hole and located in V blocks 3 and 4, which have been lined up squarely with the travel of

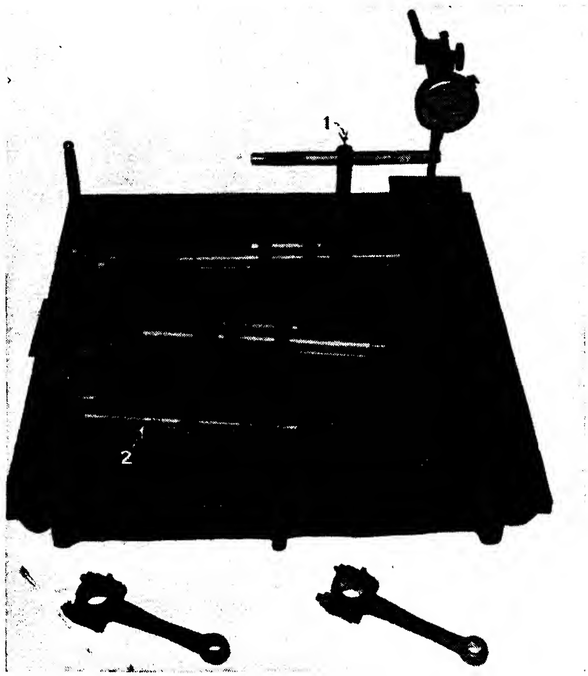


FIG. 96.—Checking parallelism of holes.

the lathe carriage. The mandrel is held in the V's by springs at 5 and 6. The first bore is positioned by placing the cylinder block against the stop 7. Reversing, this stop positions it for the second bore. Wedge clamp 8 holds the cylinder against the stop but without exerting pressure on the cylinder walls.

The lower edge of the cylinder is milled parallel with the crankshaft bore and is located on a button on plate 9, just below the center of the boring bar 12. Clamp 10 gives a spring tension against the button and so avoids any tendency to distort the

cylinder bore. This method has the further advantage of giving the operator a clear view of the work at all times. The bore is 1.25 in., the bar runs at 1,700 r.p.m. giving 556 ft. per minute cutting speed with a feed of 0.0015 in. per revolution.

Utilizing a Used Lathe.—Mr. Evans prefers a lathe that has been used, as it has completed its cycle of distortion, and the ways, when scraped true, will remain so. The spindle should be the best obtainable and in perfect balance at its cutting speed.

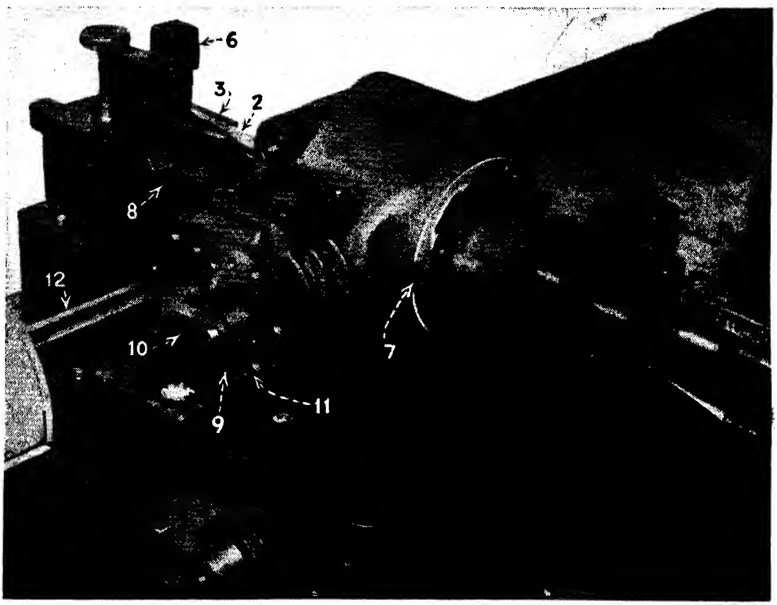


FIG. 97.—Keeping cylinder bores parallel.

It should be driven by a thin, flexible, endless canvas belt. The lathe bed should have but one V which should be parallel to a flat on the other side, as the one essential is to obtain a straight-line movement.

It is important that the material being cut should be uniform so that the cutting action of the tool will not vary. The tool must be kept sharp. All parts affecting the movement of the carriage must be kept free from chips, as should the fixtures used. A separate motor is used for the feed and neither motor is mounted on the lathe bed, to avoid vibration. The feed of

the carriage should be as near the center of the work as possible. Temperature of work and spindle should be kept constant while work is being done. Clamping should not distort the work in any way. Final scraping and adjusting of the machine should be done after it is fastened in place.

Importance of Accuracy of V Blocks.—To secure good work it is essential that the V blocks be square with the ways of the lathe bed. This is done as in Fig. 98. A 36-in. steel scale is clamped to the carriage as at 1 and traversed past a stationary

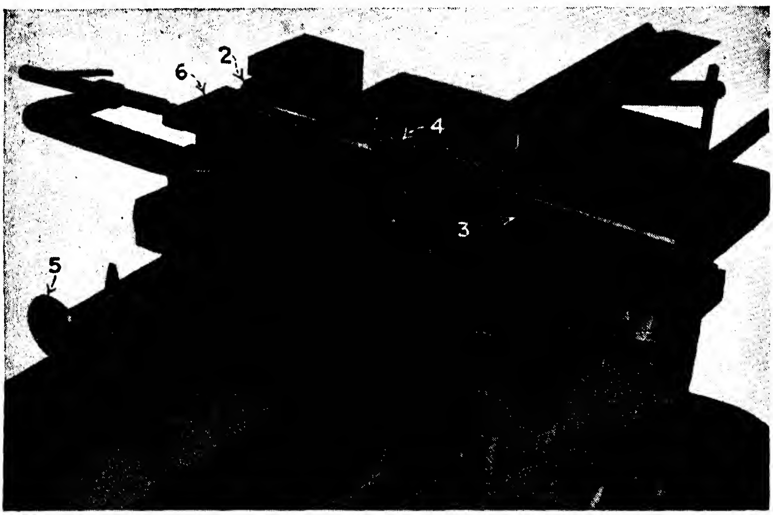


FIG. 98.—Checking accuracy of V blocks.

one-tenth indicator until a zero reading is obtained. It is then clamped in place. V blocks 2 and 3 are then mounted on the surface plate and adjusted so that the mandrel 4 and the indicator 5 are at right angles when swung to the other end of the scale. The plate 6 has a ball that bears against the mandrel to act as a stop while tramming. The V blocks can then be clamped in place with the assurance that they are square with the ways of the lathe bed.

Using an Angle Plate.—With the V blocks mounted on a surface plate on the lathe carriage it is easy to use these V blocks for other work (Fig. 99). The axes of these V blocks must be square with the travel of the carriage. With this equipment

it is easy to remove one job and replace it with another. Two master angle plates 1 and 2 are assembled on mandrels 3 and 4, with a dowel at one end. At the other end of the angle plate is an adjustable stop against which the mandrel is held by clamp 5. The flat side of the mandrel is held against the under side of the angle plate by screws, using a thin paper gasket close around each screw. This was found necessary to avoid distortion, even though the flat on the mandrel was lapped. The axis of the mandrel is made parallel with the face of the angle plate by laying the plate on true parallels on a surface plate

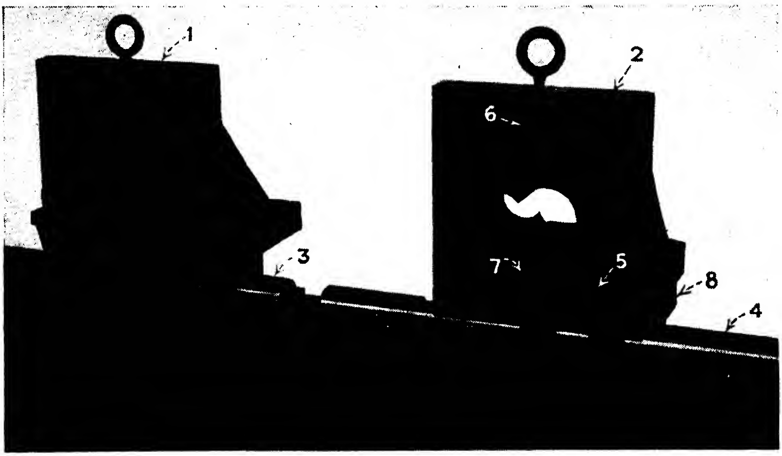


FIG. 99.—One way of using angle plates.

and indicating across the ends of the mandrel. On the rear of the angle plate is a stop by which the front surface of the plate is made square with the travel of the carriage.

Any job with a true face clamped against the angle plate by clamps such as 6 and 7 can be placed on any lathe fitted with square V blocks, and holes can be bored square with its face. Parallel holes can be bored any distance apart by using the locating point 8. Work can be moved from one lathe to another for subsequent operations if each lathe has accurate V blocks on the carriage, and accuracy is assured. Changes from one set-up to another can be quickly made and with accuracy to a tenth.

A Typical Set-up.—A typical set-up is shown in Fig. 100 where the lapped face of a cylinder is placed against an angle plate

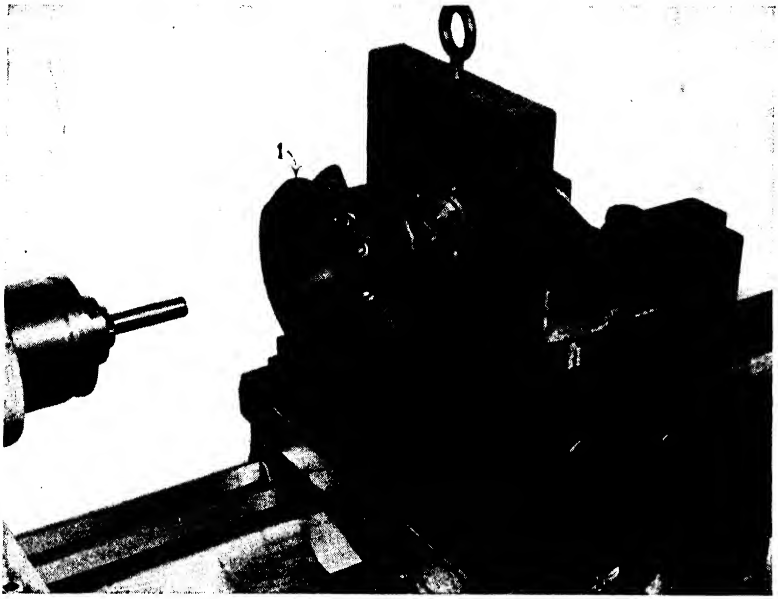


FIG. 100.—A typical cylinder set-up.

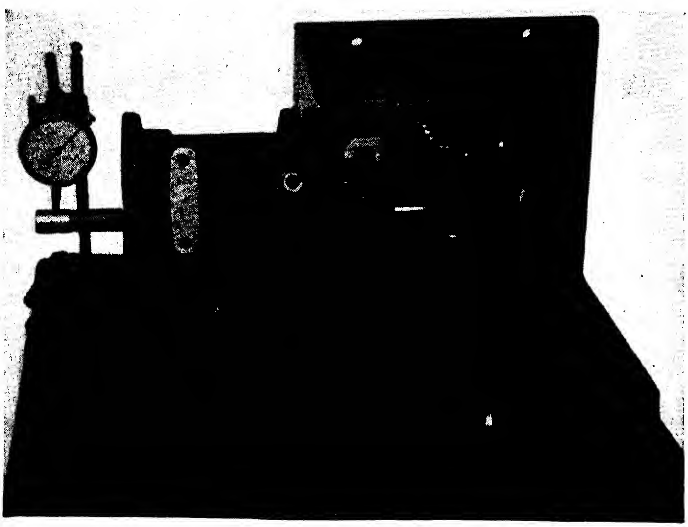


FIG. 101.—Checking accuracy of hole.

after being roughly located by a plug. The hole is then bored square with the face. The hole is checked for accuracy by the methods shown in Figs. 101 and 102. Here the cylinder is lined

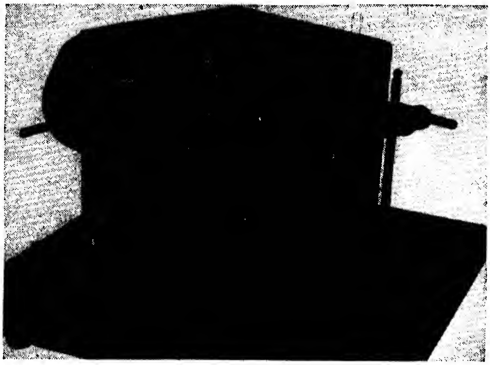


FIG. 102.—Back side of the checking fixture.

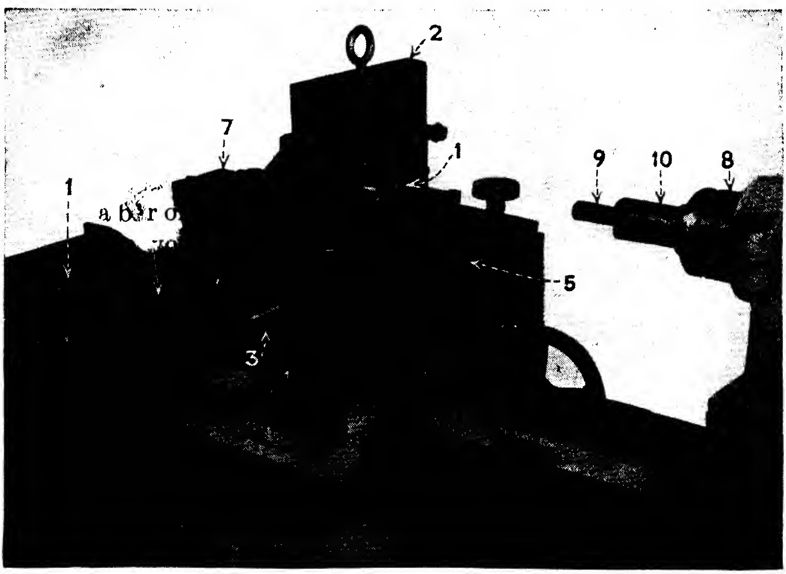


FIG. 103.—Details of set-up for close work.

up on a three-sided angle plate which in turn rests on a surface plate. The two views show how alignment can be checked with test bars and surface gages.

Another application of the principle is seen in Fig. 103. Here it was necessary to bore two holes in a short cylinder. These holes had to be parallel within a tenth in 7 in. and square with the lapped face, with proper center distances. The set-up is similar to those shown before. Cylinder 1 is clamped to angle plate 2 which is positioned by the mandrel 3 in the V blocks 4 and 5. Center distance between holes is controlled by the double-ended stop 6, as shown in Fig. 103. Stop 7 makes the front face of the angle plate square with the travel of the carriage. The boring spindle 8 carries a boring bar with two tools, 9 and 10, for the two sizes of holes. The squareness of these holes is checked on one side of the angle plate in Fig. 101.

Avoid Vibration.—To secure extreme accuracy vibration must be reduced to the lowest possible amount. Motors should be mounted separately from the machine itself. The boring spindles and boring bars must be as stiff as possible. This means accurate bearings of ample dimensions and boring bars as stiff and as short as the work will allow.

BORING AND THREADING IN A LATHE

A good latheman can do a large variety of machine work. Many times he can do jobs that inexperienced men would think

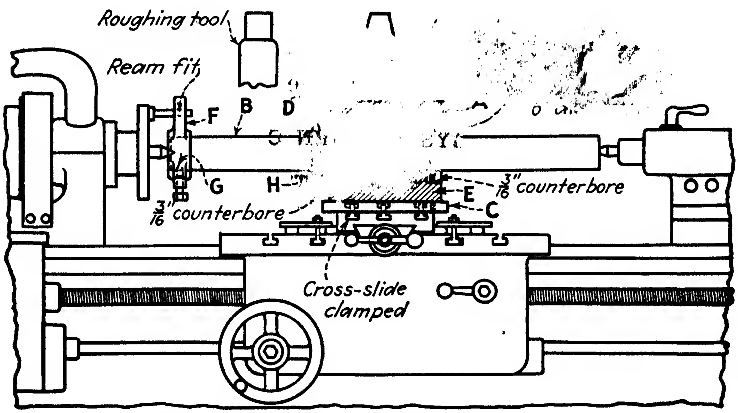


Fig. 104.—Cutting internal thread with a boring bar.

could be done only on boring machines or other machine tools. Figure 104 shows a job that came into a shop where the only machine large enough for the piece was a good lathe. The piece was a large bronze nut in which a 1-in. pitch Acme thread had to

be cut for a screw 6 in. in outside diameter. The nut, which was in halves *A* and *E*, was mounted on the plate *C* and bolted to the cross slide, while clamp *D* held the work down in plate *C*.

Boring bar *B* carried a driving dog *F* with a setscrew *G*. The dog was driven by a pin fitting through a reamed hole in *F*. This was to avoid any backlash when the lathe was reversed.

The hole was first bored to the proper size with a regular boring tool in bar *B*. Then for the first cuts in the thread the boring tool was replaced by the roughing tool shown. After the thread had been rough-cut by the first tool, it was replaced by the finishing tool, which cut the thread to the proper angle of 29 deg. and to the right depth.

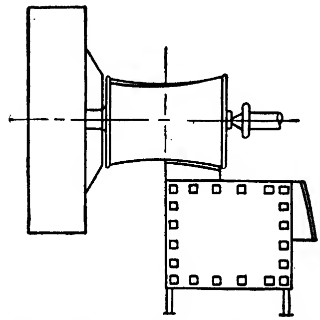


FIG. 105.—Turning large radius with wide-faced tools.

The cross slide was of course clamped to the saddle after the work had been centered. The depth of cut was secured by moving the tool by the screw *H*. With the boring bar held between the lathe centers and the work bolted to the carriage, the desired feed was secured by feeding the carriage as in regular turning or in thread cutting on a bar or screw. The only d[illegible]rence was that the carriage moved the work instead of [illegible] the cutting tool.

[illegible] CONTOURS

Rollers for 21-in. torpedo[illegible] radius of 10½ in. and were formerly turned with two form tools, one for each half of the curve, as shown in Fig. 105. The other tools faced the ends to the proper length. These broad-faced tools required considerable pressure to force them into the work and frequently dug in too deeply.

A former was put at the lathe having the proper radius and the cross-feed screw removed from the tool block, as in Fig. 106. Two roughing cuts were taken and 1/16 in. of metal left for the finishing cut. This work is now being done at the Nordberg Mfg. Co. plant in a 16-in. engine lathe, thus saving considerable time and releasing a turret lathe for other work.

A somewhat similar method is shown in Fig. 107, the former

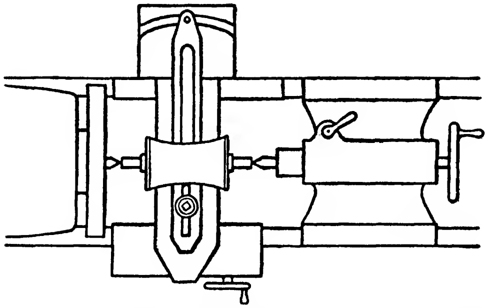


FIG. 106.—Turning same radius by former at rear.

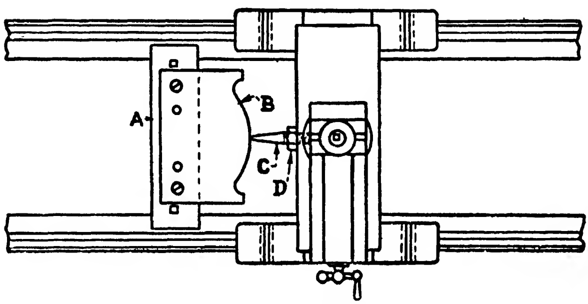


FIG. 107.—Another method of using a former for turning contours.

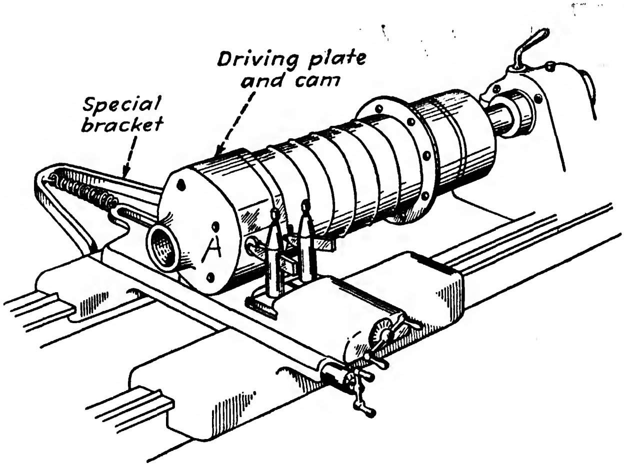


FIG. 108.—Using a cam-shaped former on the end of the work.

here being fastened across the bed to guide the tool and so forming a dome-shaped surface on the work. The guide, or tracer, can be held against the former by a weight attached to the carriage or by a spring, or can be kept in contact by the operator's left hand while his right feeds the tool across the face of the work.

The plate *A*, which is clamped to the flat part of the bed inside the ways, carries the former *B*. A hole drilled and tapped in the center of the bottom of the cross slide carries the tracer *C*, which is made of a hardened screw having a rounded end. The tracer is locked in position by the nut *D*. When the tracer has contacted the former from one end to the other, the work must be a duplicate of the former.

In Fig. 108 the upper end of a cylinder is being turned to a special contour under control of a former *A* bolted to the end of the cylinder. A spring at the back keeps the roller in contact with the former, and the tool must follow the movement of the former.

This particular job was formerly done on a vertical milling machine, as shown in Fig. 109. Here the milling cutter was guided by a collar above the cutter, which made contact as the table, or plate, on which the cylinder was clamped was rotated. It was also necessary to move the table of the milling machine to keep it in contact. Use of the lathe is a simple method of doing this particular job.

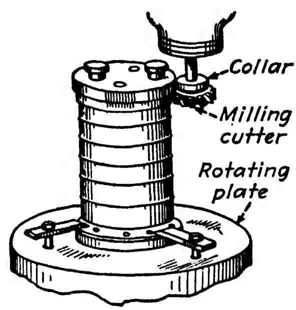


FIG. 109.—The same job done on a milling machine.

RECESSING OR UNDERCUTTING

Undercutting can be done in various ways, but best results are obtained when the tool can be controlled from outside the hole and the amount of undercut known by the position of the operating lever. The use of hook tools is not so satisfactory as is holding the cutting tool rigidly in a substantial support that reaches inside the hole.

Three methods are shown in Figs. 110, 111, and 112. The first is designed primarily for lathe work, where the tool is stationary, the work revolving around it. The bar is held on the lathe carriage. A slot through the center of the bar carries the under-

cutting-tool bit and the levers that control it. Here the tool *A* is moved by the double-ended lever *B*, pivoted near its center.

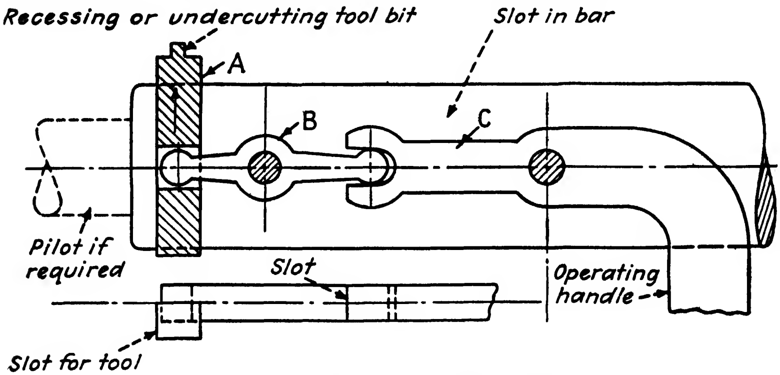


FIG. 110.—Recessing tool for use in the lathe.

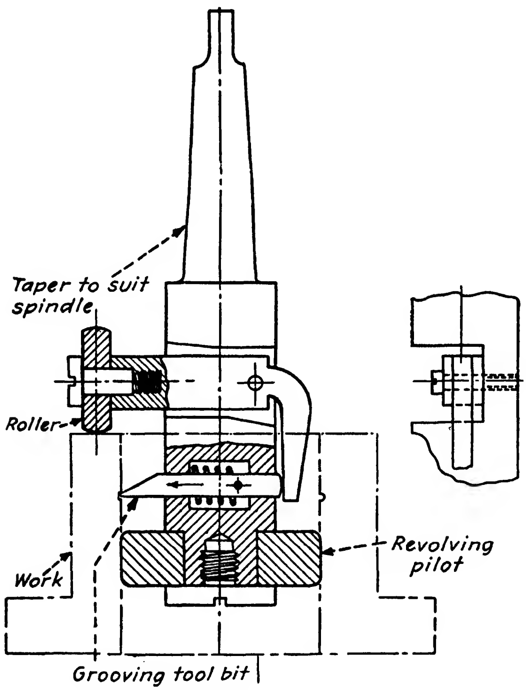


FIG. 111.—Undercutting tool designed for use in drill press.

The bent lever *C* has an operating handle that projects from the side of the bar.

A pilot can be provided to support the bar, as shown by the dotted lines. Movement of the projecting handle forces the cutter into the work and withdraws it so as to permit its removal.

The other two tools can be used in either a lathe or a drill press, although the tool in Fig. 111 is designed primarily for drill-press use. It could, however, be used in the tailstock of a lathe. Here the position of the recess is determined by the distance between the roller and the tool. As the roller contacts the face of the work, it forces the cutter into the bore as the bore is forced forward by means of the bell-crank arm in contact with the back end of the cutter. In this case a revolving pilot supports the tool in the work.

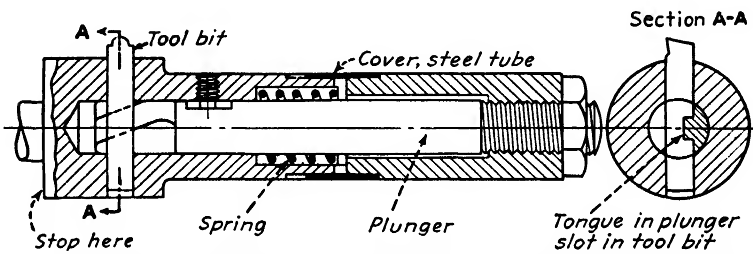


FIG. 112.—Here the tool is forced sideways when the holder bottoms in the hole.

In Fig. 112 the tool is forced into the work when the end of the bar contacts the bottom of the hole. Then, as the outer end of the bar is fed forward, the angular tongue, or cam, forces the cutting tool across the bar and into the work. The coil spring withdraws the tool from the work when pressure on the bar is released. A piece of steel tube covers the opening between the two parts of the tool shank to keep chips out of the spring chamber.

HOLDING STRAIGHT CUTOFF UNDER HEAVY FEED

Earl R. Garwood, turret-lathe operator with the Dodge Manufacturing Corporation, Mishawaka, Ind., shows how turret-lathe operators are applying their skill and ingenuity to get the highest production and accuracy from the machines and tools they have at hand.

The standard form of cutoff tool, when fed into the work under heavy pressure, tends to spring to left or right, causing a concave or convex cutoff surface. An additional facing operation

is consequently necessary to obtain a smooth finish and straight surface.

Figure 113 shows how a pilot groove ground vertically along the front clearance helps to guide the cutting tool and to prevent

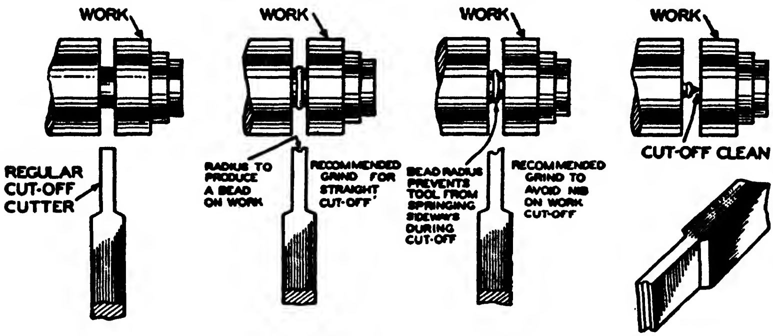


FIG. 113.—Tools for cutting off work with heavy feed.

it from springing. An angle may also be ground on the cutting tool to eliminate a nib on the cutoff workpiece.

SPRAY-METAL PRACTICE IN BUILDING UP WORN PARTS

The salvaging of worn parts of machines of all kinds is especially necessary during an emergency. One method is the building up of worn parts by a metal spray, or "metallizing." Railroad shops are using this to a large extent in salvaging piston rods and similar parts. But as the bond between the rod and the sprayed metal is purely mechanical, it is necessary to prepare the rod properly before spraying. The process differs in this respect from the building up of parts by welding.

To secure a good mechanical bond, the rod is first turned with a sharp-pointed tool, which leaves a sort of thread on the surface. Then the tops of the ridges, of threads, are flattened by using a rolling tool over the top. This forms a continuous groove, which is undercut so that the sprayed metal has a firm mechanical bond.

A high-carbon steel wire of 1.20 per cent carbon is used for the spray metal, which gives a hard-wearing surface. The piston rod is revolved at 35 surface ft. per minute, and the spray gun is fed $\frac{1}{8}$ in. per revolution. It has been found advisable to turn the rod or crankpin down enough to permit spraying up to $\frac{1}{8}$ in. of metal on the rod and to leave a built-up surface about $\frac{1}{16}$ in. thick. One piston rod built up in this way has run 165,000 miles without wearing out.

TURNING AND BORING PLASTICS

Plastics, according to John Sasso, are poor conductors of heat. Therefore, heat generated by the friction of cutting tools has to be carried away by the tool, by the air stream, or by coolant. Most machining of plastics is done dry. Since some compounds of the new setting plastics, such as the phenolics of ureas, frequently contain abrasive fillers, tools may be dulled easily. Under conditions of improper speeds and rates of feed, tools may even burn. Another phenomenon that must be taken into account is the softening tendency of some plastics. In the machining of these, the friction heat generated will heat up the plastic surface, causing it to become gummy. As a result, the tools build up a film of burned resin. In the case of high-speed drills this causes sticking and possible cracking.

Using More Rake on Tools.—In turning, facing, and boring operations on phenolic molded parts, tools having less clearance and more rake than those used for steel or other metals are recommended. Cutting speeds are 200 to 600 ft. per minute for high-speed steel tools and 500 to 1,500 ft. per minute for Stellite tools.

In the turning of acetate and polystyrene molded parts, tools should have 0 rake and plenty of clearance set at an angle of 60 deg. to the spindle. Cuts should be made at a surface speed of 65 ft. per minute and a feed of 0.010 in. per revolution. A smooth surface is obtained with a 0.020 in. depth of cut.

In the turning of cast phenolics, tools commonly are given zero or slightly negative back rake and 15- to 18-deg. clearance. Tools must be sharp, and best results are secured when the chips are ribbonlike. For the facing of cast phenolics, tool speeds range from 450 to 6,000 ft. per minute. Facing tools sometimes are set slightly above center. Too pointed an edge on facing tools tends to create chatter. On rod machines, formed circular cutters and cutoff tools can be used to advantage, or cutoff can be done with a saw.

Turning acrylic plastics is done with tools having 0 rake and plenty of clearance, set at an angle of 60 deg. to the spindle. Cuts should be made at a surface speed of about 65 ft. per minute and a feed of 0.010 in. per revolution. A smooth surface is obtained with a 0.020 in. depth of cut.

For parts molded of vinyl plastics, simple turning, facing, boring, and chasing operations are performed satisfactorily with

most ordinary metal-cutting tools provided that the front and side clearances of the tool are increased by about 50 per cent over the clearances used to machine steel. The added clearance reduces the rate of heat formation and produces good surface finishes and free-flowing chips. An increase in rake angle, made by hollow-grinding the top cutting face, offers some advantages in directing the chip away from the work. However, the accompanying reduction of cutting angle results in greater tool wear. With a surface speed between 250 and 300 ft. per minute, depths of cut can be as high as $\frac{1}{4}$ in., and rates of feed up to 12 in. per minute are possible. Higher speeds and feeds can be used with lighter cuts.

Cutoff at Slow Speed.—Cutoff tools should also be ground with increased front and side clearances. When such tools are used, the surface speed should be reduced to approximately one-half that used in turning. Slower speeds tend to roughen the cut surface, whereas faster speeds may cause overheating of the material.

For screw-machine operations on laminated tubes it is better to specify a smaller inside diameter than is required for finished size or to use laminated rod and drill it to size. Recommended cutting feeds are 0.007 to 0.015 in. per revolution for drilling, 0.010 to 0.015 in. per revolution for turning, 0.002 to 0.005 in. per revolution for cutoff, and 0.002 to 0.003 in. per revolution for forming.

The following spindle speeds are recommended for hand-screw machines: 1 in. diameter and over, 800 to 1,000 r.p.m.; under 1 in. diameter, 1,500 to 2,000 r.p.m.; $\frac{7}{16}$ to $\frac{5}{8}$ in. diameter, 3,600 r.p.m.; $\frac{1}{8}$ in. diameter and under, 5,000 r.p.m. Flooding with lard oil and kerosene tends to increase production and to prolong tool life.

MACHINING ALUMINUM

General Characteristics of Tools.[1]—Although the machining properties of the various aluminum alloys differ, the chief dissimilarities between the use of tools for aluminum and for most other metals, which should be carefully observed, are as follows:

1. Grind more top and side rake on the cutting tools than is common for machining steel.

[1] Suggested by the Aluminum Company of America.

2. Keep cutting edges sharp and free of burred or wire edges.
3. Maintain smooth bright tool surfaces free from scratches.

Tool Materials.—Tools of plain high-carbon steels frequently perform satisfactorily when machining aluminum and most of its alloys. Under conditions in which the cutting speeds are necessarily low, they may be the most economical, particularly for small-diameter drills. For quantity-production work, tools made from high-speed steels have largely replaced the carbon-steel tools, but, in many instances, tools tipped with sintered carbides have proved far superior to high-speed steel tools. Tools of this last type are especially suited for the machining of aluminum alloys of high silicon content; in fact some of these alloys cannot be matched successfully under production conditions without it. The sintered-carbide-tipped tools, when ground to proper rake angles, produce excellent machine surfaces and remain sharp for long periods of time without needing regrinding; consequently these tools are economical for high-rate production. The use of sintered-carbide tools is, of course, restricted to operations in which the work is free from vibration and irregularities in the cut.

Tool Shapes.—In general, the larger rake angles are employed for finishing tools and for the aluminum alloys that are not free cutting; this includes the softer materials that require tools with exceptionally acute and keen cutting edges. On the other hand, rake angles in the lower range are used for roughing cuts and for machining the alloys that have free-cutting characteristics. Tools similar to those used for machining steel may often be employed successfully.

Top rake generally varies from 20 to 50 deg. Very finely finished surfaces may be produced with tools having a top rake angle in the higher end of the range, but, obviously, such a tool can be used only in a machine that is sturdy and free from vibration and that has no lost motion in the feeding mechanism. For some operations it may be necessary to use a top rake smaller than that indicated by the above range, but a negative rake should never be used.

Side rake is important in the machining of aluminum and its alloys as this produces a slicing action that is especially effective in parting the cutting from the stock. A side rake of from 10 to 20 deg. assists materially in the cutting action of the tool.

Planer and shaper tools may have a considerable amount of side rake; finishing tools have been ground with a side rake as high as 60 deg. in order to secure the best results.

TABLE IX.—CUTS, SPEEDS, AND FEEDS IN THE MACHINERY OF ALUMINUM ALLOYS

(See note)	Rough-machining			Finish-machining		
	Max. cut, in.	Speed, ft. per min.	Feed, in.	Cut, in.	Speed, ft. per min.	Feed, in.
Lathe-turning						
Type I castings, not heat-treated	0.25	500–900	0.020–0.030	0.002–0.010	Maximum	0.002–0.010
All others	0.19	400–800	0.007–0.020	0.002–0.010	600–900	0.002–0.010
Boring						
Light duty (1–2 in.)	0.09	Maximum	0.010–0.020	0.010–0.020	Maximum	0.001–0.005
Medium to heavy duty	0.25	600–1000	0.007–0.015	0.010–0.020	600–1000	0.001–0.003

NOTE: Depth of cut is the amount on each side, or the radial. Maximum means the highest speed available on most machine tools.

The clearance should be about 8 to 10 deg. and must be carried around the side of the tool that advances into the work. This angle is important. If it is too small, the side of the tool will rub against the work and generate heat. If too large, the tool may tend to dig into the work or to chatter.

In all cases it is essential that the cutting edges be keen, smooth, and free from grinding-wheel scratches, burrs, or wire edges. Too much emphasis cannot be given to tool finish, because on it depends, to a large extent, the success of machining aluminum and its alloys. Keen edges are best obtained by finish-grinding on a fine or very fine abrasive wheel, then hand-stoning with a fine or very fine oilstone, or lapping, taking care that neither the angles nor the contour of the cutting edges are appreciably modified during the finishing operations. Where possible, sintered-carbide tools should be diamond-lapped.

MACHINING N.E. (NATIONAL EMERGENCY) STEELS

In the turning of the National Emergency steels in the annealed or normalized state with high-speed steel tools, surface speeds run

from 48 to 130 ft. per minute for light cuts, the higher speeds being used for fine feeds. With heavy cuts, surface speeds will run from 25 to 50 ft. per minute. Single-point tools should have side-rake angles of 16 to 20 deg., back-rake angles of 3 to 5 deg., side cutting-edge angles of 10 deg., and end and side-relief angles of 3 to 6 deg. (see Figs. 114 and 115).

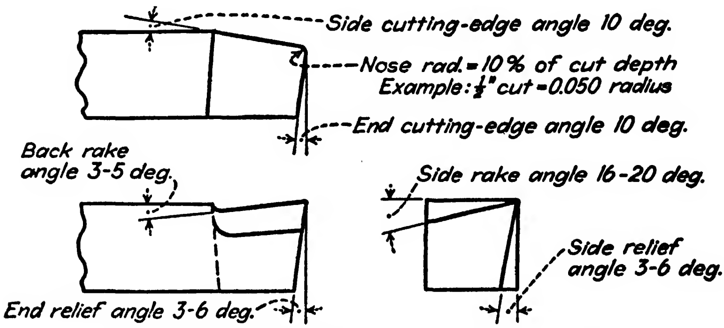


FIG. 114.—Suggested angles for tools for N. E. steels.

In the machining of these steels with sintered-carbide tools, the same tool angles should be employed as are used on the S.A.E. steels. For cuts ¼ in. or deeper, a side-rake angle of 4 deg. is recommended. For cuts lighter than this, the side-rake angle of 8 deg. can be used. A back-rake angle of 0 deg. is usually

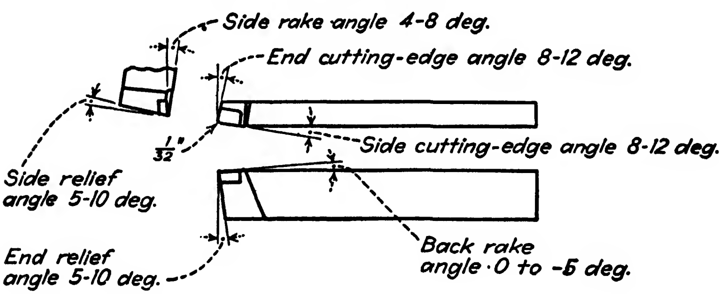


FIG. 115.—Carbide-tipped tools for N. E. steels.

satisfactory for most jobs. These values of side-rake and back-rake angles are based upon the use of an ordinary single-point tool in a lathe. Tools of other types or tools held in such a manner that the relation of the tool to the work is changed considerably from this standard turning-tool setup should have the angles changed to correspond. For example, on a plunge cut,

such as is involved in a grooving operation, a back-rake angle of between 4 and 8 deg. and a side-rake angle of 0 deg. are recommended. Side- and end-relief angles of 7 deg. are satisfactory for turning these steels, although these angles may vary from 5 to 10 deg., depending on the nature of the cut being taken.

For interrupted cuts on lathes or planers, it is desirable to use a tool with a negative back rake as great as 8 deg. in combination with 10 deg. or more side rake.

When sintered-carbide tools are used, soluble-oil coolants are recommended.

Cutting Oils for Boring and Turning.—For N.E. 8000 grades, except 8339, 8442, 8630, 8735, 8739, 8744, 8749, 8949, and for N.E. 9415, 9420, and 9422, use 20 to 25 parts water, 1 part soluble oil, and 10 to 15 parts sulphurized mineral lard oil.

For N.E. 1300 grades and N.E. 8339, 8442, 8630, 8735, 8739, 8744 and 8749, use 15 to 20 parts water, 1 part soluble mineral oil, 10 to 15 parts sulphur-based mineral oil, and 1 part straight mineral oil.

For N.E. 8949, 9500, 9600, 9200, 9210, and 9400 use 5 to 10 parts water, 1 part soluble mineral oil, 10 to 20 parts lard and sulphurized mineral oil, and 3 to 4 parts straight mineral oil.

Makers of Kennametal tools advise against the use of sulphurized oils with these tools.

MACHINING ARMOR PLATE[1]

An outstanding difficulty in machining armor plate is that this tough and hard material has a tendency to work-harden. It is importanւ to use tools that are as free cutting as possible. Another thing to remember is that while armor-plate castings have heavier sections than those customarily found in ordinary steel castings, they flex more easily under pressure—returning to their original state when the pressure is released. This is an important consideration in finish-machining and also in the selection of depths of cut for roughing and finishing.

The dimensions of carbide tips to be used on cutting tools for cast armor plate may vary considerably, depending on the individual operation. In general, tips for tools to be used on interrupted cuts should be somewhat thicker than those used for

[1] These suggestions are by Fred W. Lucht, engineer of the Carboloy Company, Inc.

continuous cuts, in order to withstand the repeated impact loads. Charts that will aid in the determination of tip thickness for this class of work have been compiled and are readily available. Tips should preferably not exceed one-third of the shank height in order to provide ample support under the tip. If the tip is exceptionally wide in relation to the width of the shank, it is frequently advisable to mill off the entire front of the tool and braze the tip onto the flat surface, rather than to attempt to set it into a recess, one side of which may be too thin to be of any use in providing adequate support.

Shank materials may be either S.A.E. 9250 steel (Silman), carbon varieties ranging between S.A.E. 1050 and 1095, S.A.E. 2340 carbon type, or any low-alloy type. The cross-section of the shank for any single-point tool should be able to withstand the bending load resulting from the depth of cut and feed used for a given tool overhang. When the cut is of an interrupted nature, either use a larger shank or reduce the tool overhang to enable the tool to withstand the increased impact load.

General belief is that, in the machining of armor-plate castings, the use of the side cutting-edge angle on carbide-tipped tools protects the nose radius and for that reason tends to increase the tool life. This angle usually varies from 0 to 30 deg. Starting with 15 deg. is suggested.

When the work calls for a continuous cut, a side cutting-edge angle of from 5 to 20 deg. enables the load to be taken on the tip, at a point well back from the nose, where the tool is stronger. Sometimes the smaller 5-deg. angle may be used for taking a roughing cut. This is advantageous when one is working up to a shoulder since it leaves a decreased amount of stock to be removed in the finishing cut. However, if the work is impregnated with hard inclusions and sand pockets, and particularly if it has an irregular outline, increasing the angle to 20 deg. provides a tool life sufficiently greater more than to compensate for the slight increase in the amount of stock to be removed in finishing. On many interrupted roughing cuts it is advisable to increase the side cutting-edge angle to somewhere between 20 and 30 deg.

Increasing the side cutting-edge angle increases end pressure on the tool. Where such end pressure must be held to a minimum in order to avoid deflections in castings, a 0-deg.-side-cutting-edge-angle tool is usually most suitable. This also has the advantage

of making the tool more free cutting and of reducing the amount of power required to operate the machine. A good general rule is to lean toward the large angles for interrupted cuts and smaller values for continuous cuts.

After the best side cutting-edge angle has been established, its relationship to the side of the tool shank should be maintained in service within about ± 2 deg. (unless a closer tolerance is necessary on the part in question). This much variation will not change the cutting action of the tool sufficiently to cause tool trouble.

Correct back rake is important, because most machining operations are of the interrupted type. Here the use of negative back rake has been found highly advantageous in many applications. Tools with negative back rakes enter the cut after an interruption in such a manner that the impact load is considerably reduced and initially falls farther back on the tool where strength is greater. The tool then enters the cut with a "shaving" action, which also helps the hose of the tool since the latter will be eased into the cut with minimum impact.

When such shear-type tools with negative back rake are used, the tip of the tool is below center. This provides another advantage in that it reduces the amount of front clearance necessary and thereby strengthens the tool by providing more shank support under the nose.

This type of tool is illustrated in Fig. 116, which shows the effect of back rake on different types of cuts. At *A* and *B* are shown the plan and end views of a setup for a continuous-type cut in which 0-deg. back rake is desirable. To ensure that the nose radius of the tool is following the balance of the side cutting edge in entering the cut, one should provide a side cutting-edge angle on the tool, as shown in *A*. This takes care of the single entry of the tool into the cut required for this type of operation. Once the nose radius of the tool is buried in the cut, there is no further tendency for it to break down except through wear.

On continuous cuts where there are considerable hard inclusions or sand pockets, it is preferable to provide the tool with a small negative back rake of the general design, as shown in Fig. 116. Usually a 3-deg. effective negative back rake will sufficiently reduce the tendency for the nose radius to dig into the work as it passes hard spots and sand holes. It will also maintain the backlash in the machine in a constant direction.

Figure 116, *D* and *E*, shows how an effective negative back rake of 3 deg. is provided in the tool under other conditions. In Fig. 116, *C*, the face of the interruption on the work, approaching the tool, slopes behind the center of the work by some amount *N*. Here a 0-deg. back rake is preferable for maximum tool life. The tool takes the impact load of the work nearer the back end of the carbide blank, while the pressure of the sloping surface of the

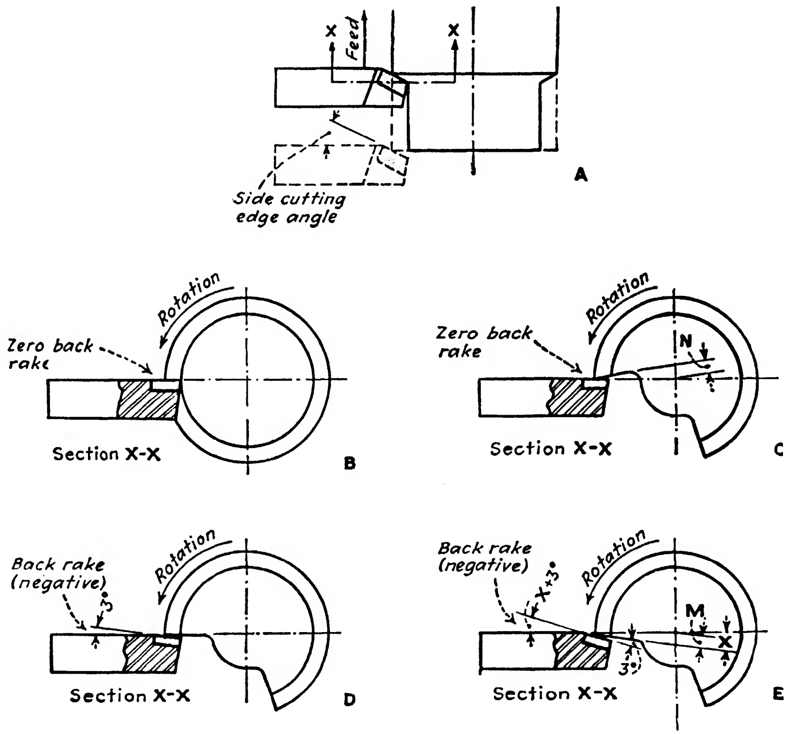


FIG. 116.—Back rake suggested for interrupted cuts.

face of the interruption on the work, taken along the side cutting-edge angle, maintains machine backlash in a constant direction. It also retards any tendency for the nose radius on the tool to dig into the work at the beginning of each cut.

When the face of the interruption on the work is negative, as shown in Fig. 116, *E*, the amount of negative back rake will have to be increased in proportion to the slope of the face, still leaving an effective 3-deg. angle between the top of the tool and the face of the interruption. Sometimes this means that the negative

back-rake angle will be as high as 35 to 50 deg. While this may seem excessive, free cutting action for the tool will be retained as long as the side-rake angle is increased to a sufficient amount, usually 10 to 25 deg.

When the face of the interruption on a casting includes several of the conditions shown in Fig. 116, *C* to *E*, the tools should be made with a back rake that will cover the most difficult condition.

Shear Tools for Castings.—The type of tool under discussion is shown in Fig. 117 and is known as a *shear* tool. While this

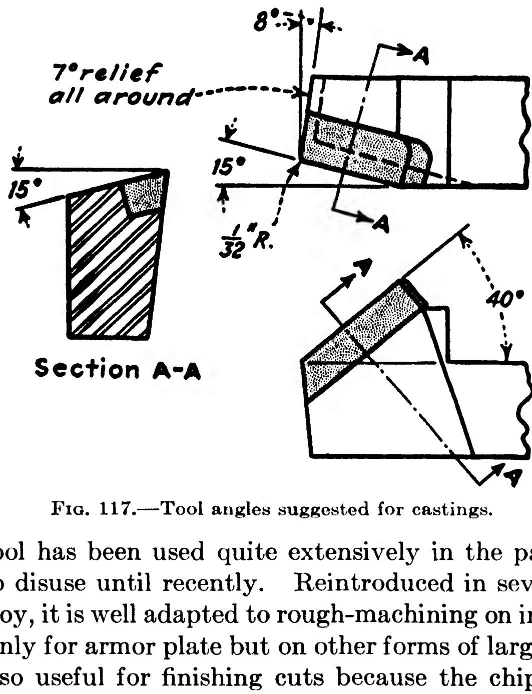


FIG. 117.—Tool angles suggested for castings.

type of tool has been used quite extensively in the past, it had fallen into disuse until recently. Reintroduced in several shops by Carboloy, it is well adapted to rough-machining on interrupted cuts not only for armor plate but on other forms of large castings. It is not so useful for finishing cuts because the chip is curled toward the finished surface and has a tendency to mar the finish. General design of the tool limits its use to shanks approximately 1-in. square or larger.

General indications are that when interrupted cuts are taken on armor-plate castings, a side-rake angle of between 5 deg. positive and 3 deg. negative provides best tool life. The larger positive side rake improves free cutting action. If the cut is continuous, it is best to start with a 5-deg. positive side rake. When the

surface of the work is hard and scaly and contains hard inclusions and sand pockets, the side rake may be reduced to 0 or even −3 deg. in order to reduce the tendency to chip the side cutting edge and thereby to reduce tool life. This applies to continuous as well as to interrupted cuts.

Negative Side Rake Seldom Used.—On tools with a large side cutting-edge angle and a negative back rake, negative side rake should never be added unless it becomes absolutely essential for tool life, since a negative side rake under such conditions retards the free cutting action of the tool. The double negative rake angles on such tools also become objectionable at times because of the added strain that they place on both machine and fixture. When it is necessary to mount a tool with considerable overhang, as sometimes occurs in boring mills, the use of tools with double negative rake angles frequently limits the possible machine speed and feed.

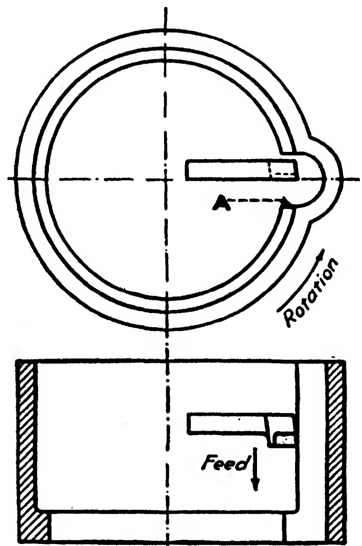


Fig. 118.—Where double negative rake may be used.

An exception to the objection to double negative rake angles is illustrated in Fig. 118. This may occur quite frequently in rough- or finish-turning, facing, or boring interrupted cuts up to a shoulder. Under such conditions tool requirements call for a 0-deg. side cutting-edge angle, and here the double negative rake angles may be used to increase tool life and to facilitate holding to tolerances. In such an application a tool has a tendency, during the entire length of the cut, to move outward in the direction of the nose radius whenever the open space in the cut passes the tool. Here the tool may be given a 3-deg. negative back rake to prevent it from being damaged under impact by the approach portion of the interruption *A*. When this tool reaches a shoulder at the end of the cut, it has a tendency to move in the direction of the feed when the open space in the cut passes the

tool. To prevent the tool from being damaged under these conditions, as well, the face of the tool should also have a 3-deg. negative side rake.

The end cutting-edge angle may vary between 8 and 30 deg. Starting with 8 deg. is suggested. In general, it is desirable to hold the end cutting-edge angle down as low as possible to give maximum strength to the nose of the tool. For continuous cutting in fairly clean armor-plate castings, this angle may vary from 8 to 15 deg. for ordinary operations. Where there are hard spots or sand pockets, or where the cut is interrupted, the 8-deg. angle supports the nose radius best.

Power for Heavy Cuts on Cast Armor Plate.—Cutting horsepower = depth of cut in inches × feed in inches × surface speed per minute in feet × constant. A good average constant is 10. Friction horsepower of the machine, usually 30 per cent, must be added.

Example.—Depth of cut 0.25 in., feed 0.10 in., cutting speed

$$50 \text{ ft.} = 0.25 \times 0.10 \times 50 = 1.25.$$

Multiplying by constant, 10 = 12.5 hp. Adding

$$30 \text{ per cent} = 12.5 + 3.75 = 16.25 \text{ hp.}$$

Roughing Cuts in Armor Plate.—Tools, as shown in Fig. 117, have been found useful for rough cuts and interrupted cuts on armor plate.

TABLE X.—CUTTING SPEEDS* FOR STEEL OF VARYING HARDNESSES†
Kennametal cutting tools

Hardness of work			Suggested speed surface, f.p.m.
Rockwell C	Brinell	Scleroscope	
65	682	93	20– 30
60	601	83	30– 50
55	545	75	50– 60
51	495	69	60– 80
45	427	62	80–100
40	370	54	100–150
35	323	46	150–220
30	276	42	220–300
25	249	38	300–400

* Suggested by the makers of Kennametal cutting tools.

† For steel softer than any of these, use any speed above 250 ft. per minute.

CHAPTER VII

EXAMPLES OF MODERN LATHES

The foregoing pages have shown the principles of lathe construction and operation. We now show some of the modern machines and details which were unknown in earlier lathes. While each lathe builder has developed special designs for his particular product, and all have advanced in ability to do more and better work, it is possible to show but a few of the new features as being typical of the progress made. Motor-driven

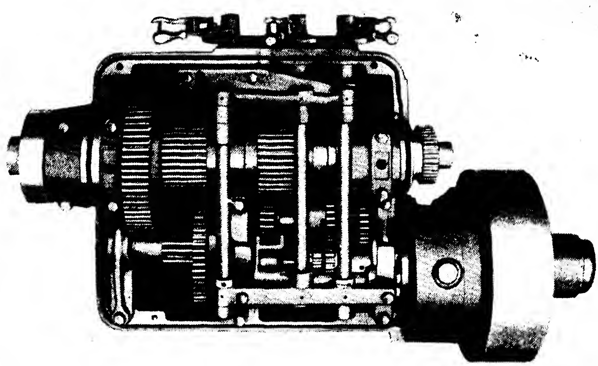


FIG. 119.—Lodge & Shipley headstock gearing.

lathes are no longer unusual and headstocks in which selective gears have replaced the cone pulley are the rule.

Such a headstock, as made by the Lodge & Shipley Machine Tool Co., is shown in Fig. 119. In this design, the gears shown give 12 changes of spindle speeds ranging from 8 to 313 r.p.m. on the 24-in. lathe. The feed mechanism is shown in Fig. 120. Over 50 pitches of threads, from 32 per inch to 2-in. leads can be cut and feeds of 0.0114 to 0.727 in. per spindle revolution, can be had without changing gears. Compact and convenient draw-in chucks and collets for these lathes are seen in Fig. 121.

Engine lathes are also equipped with front and rear tool blocks and with stops for setting both diameters and shoulders, as in Fig. 122. A modern taper attachment is seen in Fig. 123.

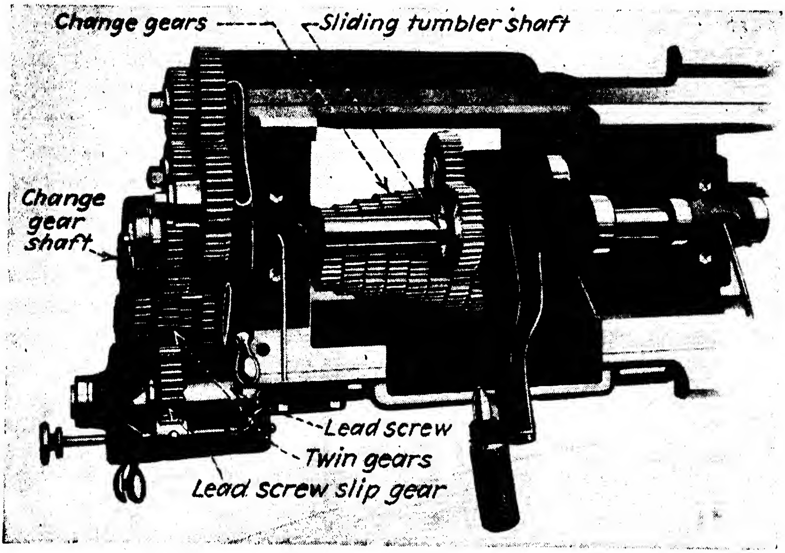


FIG. 120.—Feed gearing in same lathe.

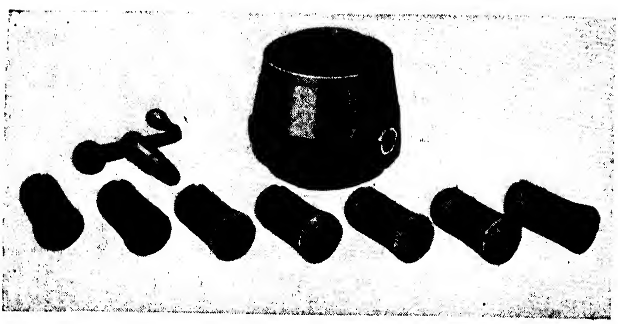


FIG. 121.—Draw-in chuck and collets.

Other special features, as used on lathes of the American Tool Works, are shown in Figs. 124 to 127. Figure 124 shows the carriage fitted with a square turret tool post, a rear tool post, and adjustable stops for feeding the tools in to predetermined diameters. This lathe also has longitudinal stops. An interest-

ing chip breaker, which prevents the long curling chips that were once the pride of the machinist, is seen in Fig. 125. With the high cutting speeds possible with cemented-carbide tools,

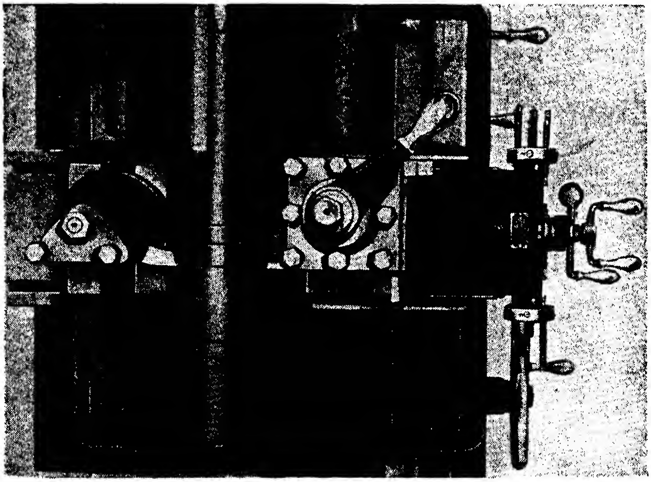


FIG. 122.—Shoulder stops for tool carriage.

the long curling chip is a menace, as to both burns and mechanical injury.

Two other special features of these lathes are the large diameter direct-reading cross-feed dials (Fig. 126) are the roller-bearing center that is built into the tailstock spindle. It is also of interest to note the ball-thrust bearing at the back end of the tailstock screw, also in Fig. 127. The American Tool Works also have a compensating device that insures accuracy of shoulder lengths, regardless of the depth of the centers in the bars. These are a few of the reasons that modern lathes are so much more productive than those of ten and twenty years ago.

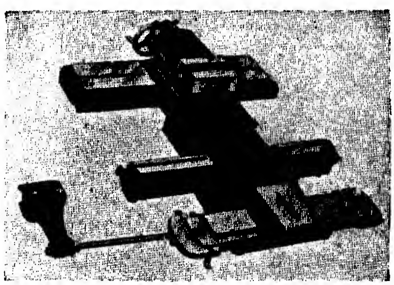


FIG. 123.—A modern taper attachment.

The type of bearing best adapted to modern lathe spindles and other parts is by no means settled in the minds of either

builders or users. While some of the well-known lathe manufacturers still believe that accurate plain bearings are best, one well-known make, the Monarch, uses antifriction bearings throughout, as can be seen in Fig. 128, which shows the headstock, feed mechanism, and carriage. These bearings include both straight and tapered rollers and balls, the latter almost

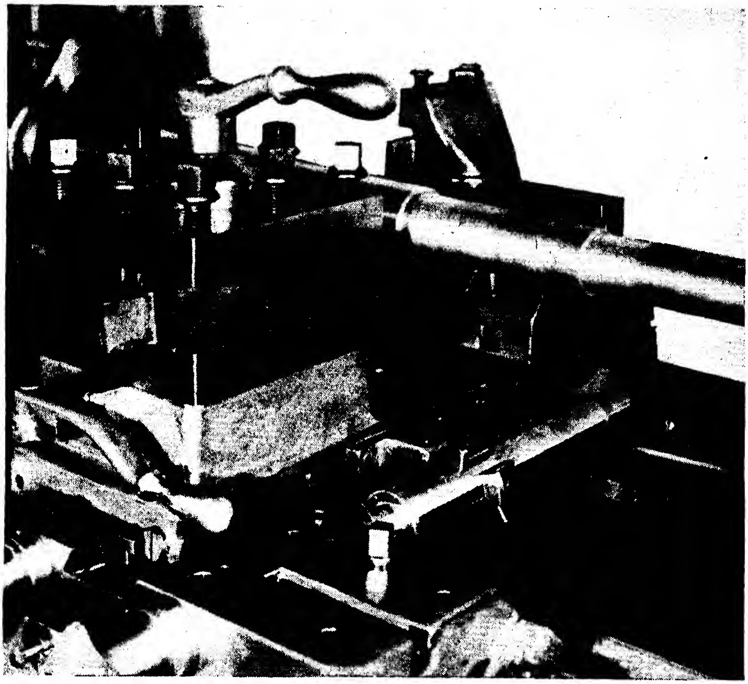


FIG. 124.—Square tool post, and stops, in American lathe.

exclusively for thrust loads. This use of antifriction bearings extends to the cross-feed screw and the compound rest as can be seen. Most lathe builders also use antifriction bearings.

Monarch as well as some others also supplies a subhead that bolts to the lathe bed in front of the spindle for chasing threads with extremely coarse leads or for relieving or backing off. The Monarch has a 6-to-1 gear reduction, making it possible to chase threads, or helices, up to 6 in. per revolution on the smaller lathes and to 12-in lead on larger lathes.

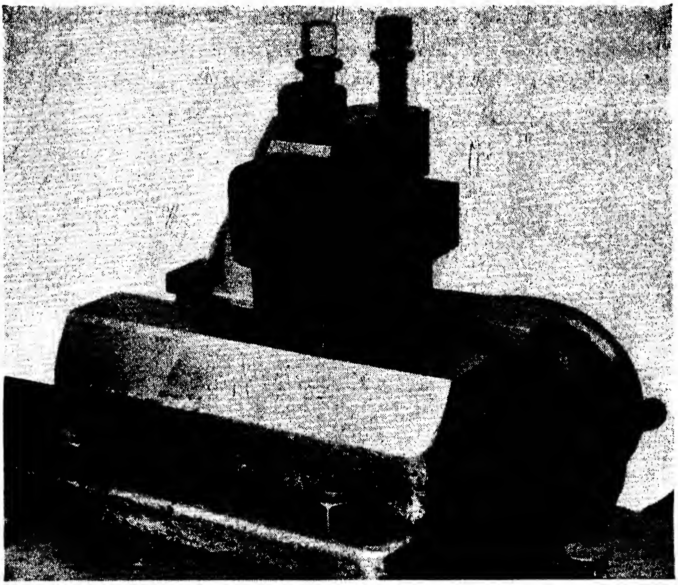


FIG. 125.—Chip breaker on turning tool.

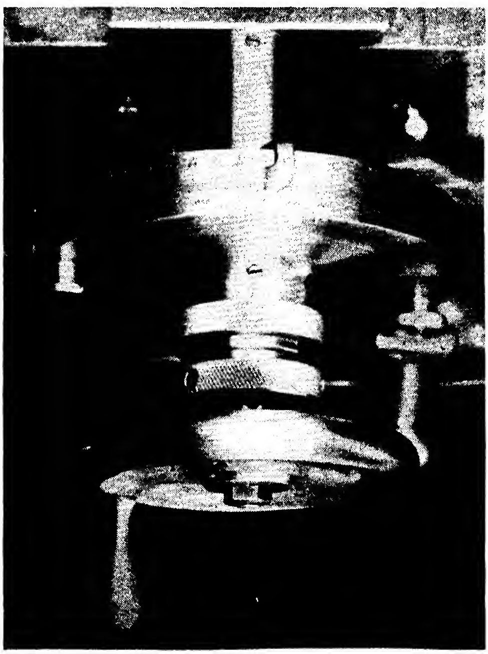


FIG. 126.—Direct-reading cross-feed dials.

Lodge and Shipley Duomatic Lathe.—Several builders also make modifications of their regular engine lathes to adapt them to large production by the use of multiple cutting tools and stops. Some of these modifications put these machines almost if not

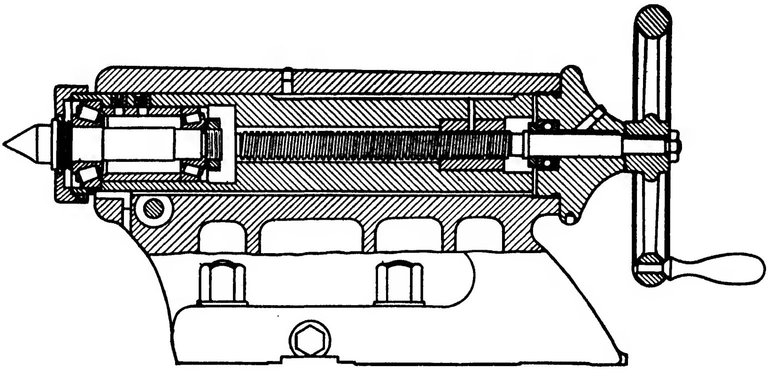


Fig. 127.—Roller-tail center with ball-thrust spindle.

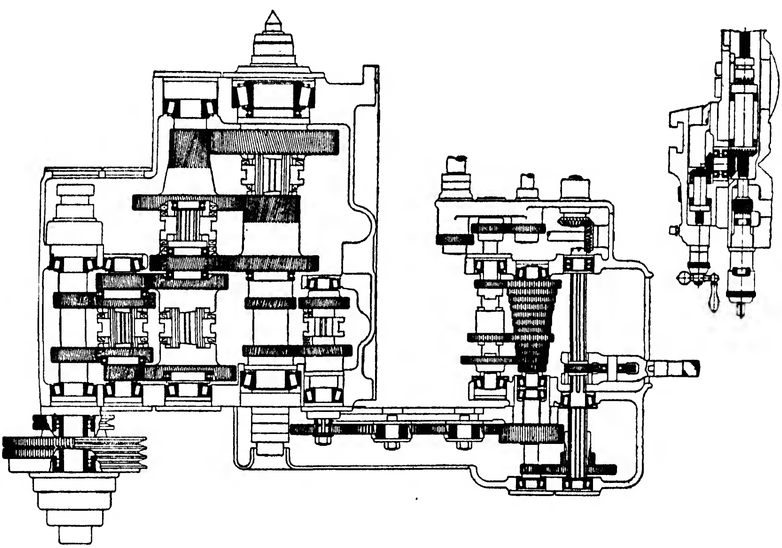


Fig. 128.—Antifriction bearings in Monarch lathe.

quite in the semiautomatic class. This is accomplished by the use of double carriages, each with special tooling, as can be seen in work being done and on the Lodge and Shipley Duomatic (Figs. 129 and 130). In Fig. 130 a steering knuckle is being turned

by two sets of tools, front and back. The taper is secured by the small taper slide at the bottom of the illustration. Figure 131 shows two set-ups of what is known as a cluster gear of an auto-

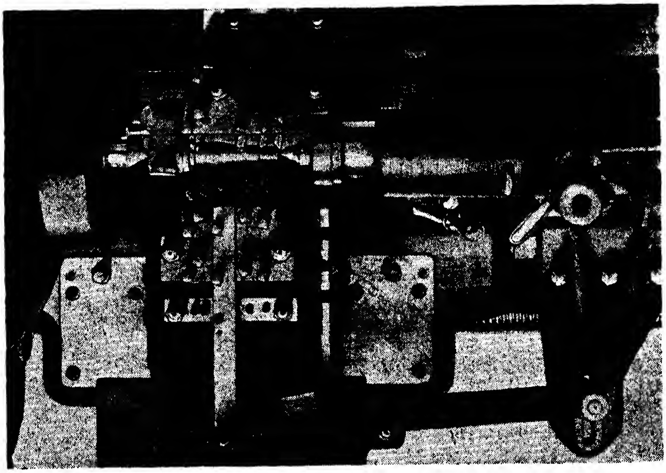


FIG. 129.—Tool set-up on Lodge & Shipley duomatic lathe.

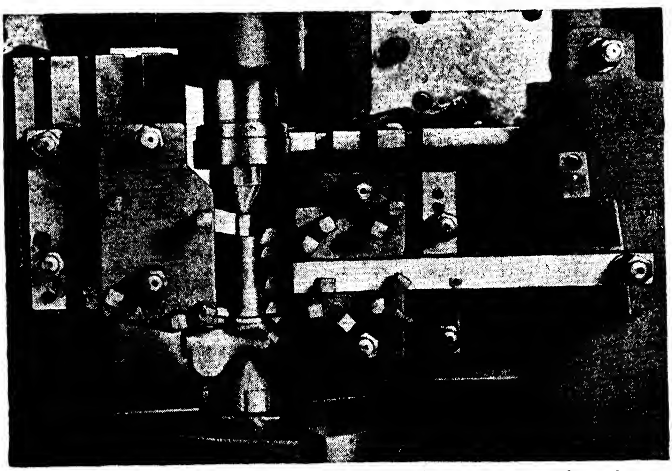


FIG 130.—Another tool set-up on steering knuckle and work.

mobile transmission. It is driven by two studs on the driver. Outside diameters and the necks are being turned and the sides faced. This job is largely done by in-feeding of the rear tool

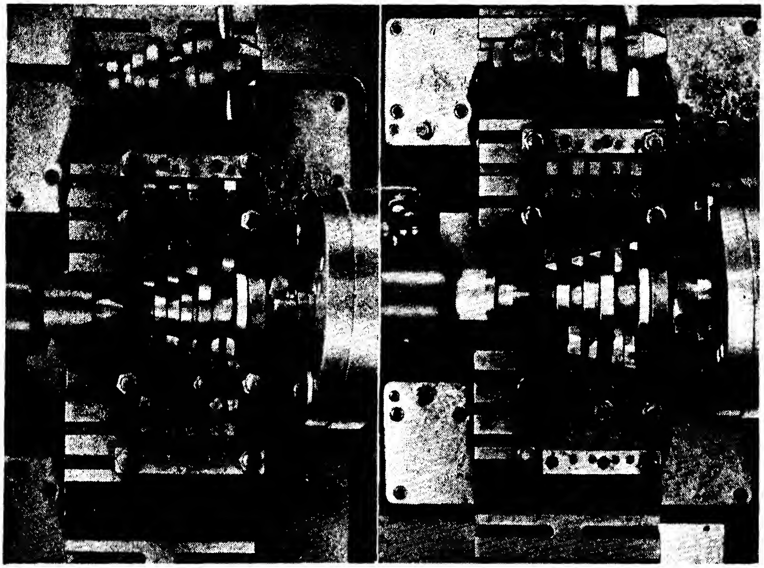


FIG. 131.—Two tool set-ups on cluster-gear work.

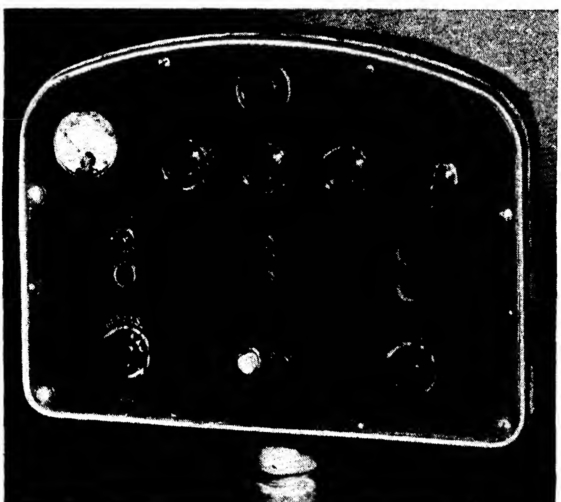


FIG. 132.—Control panel of Monarch all-electric lathe.

slides, and the traverse of the front tools at the same time. The driving mandrel is shown, loaded, on the front of the carriage. In some cases the tools turn the shaft by dividing the travel of the tools through multiple tooling. It should be noted in all the cases that each tool is backed up by a screw which permits careful adjustment and prevents it from backing out under the cut.

Monarch All-electric Lathe.—The Monarch Company has also developed an all-electric, automatic double-carriage lathe

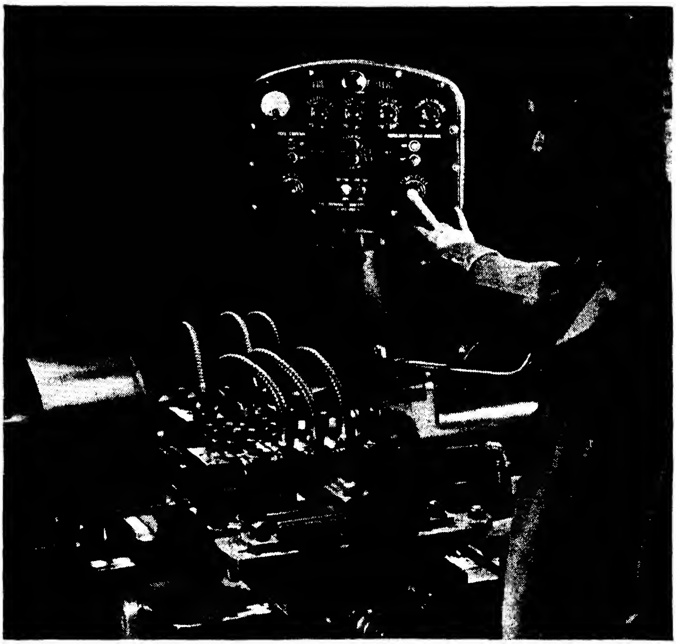


FIG. 133.—Control panel in use.

that can be used with a single tool in one carriage, or multiple tools in both. The tools are controlled by a templet as to both diameter and length of travel. The feed per spindle revolution changes automatically with the diameter being turned. The control panel is shown in detail in Fig. 132 and in use in Fig. 133. In Fig. 134 is a diagram of the kind of templet used and the way in which it controls the single-point tool used on this job. Two diagrams showing the use of the back carriage and

boring bar are given in Fig. 135. The total average set-up time for a new job is given as 20.5 min. Once set up on a new job, all

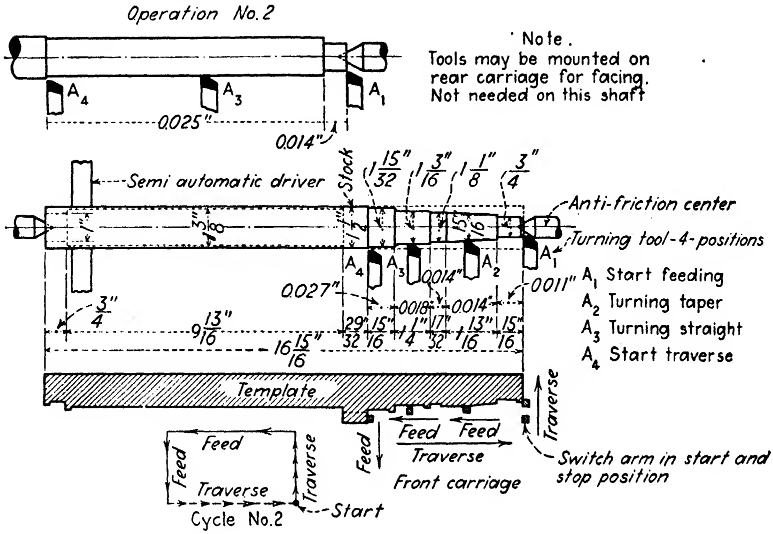


FIG. 134.—Templet control for turning tools.

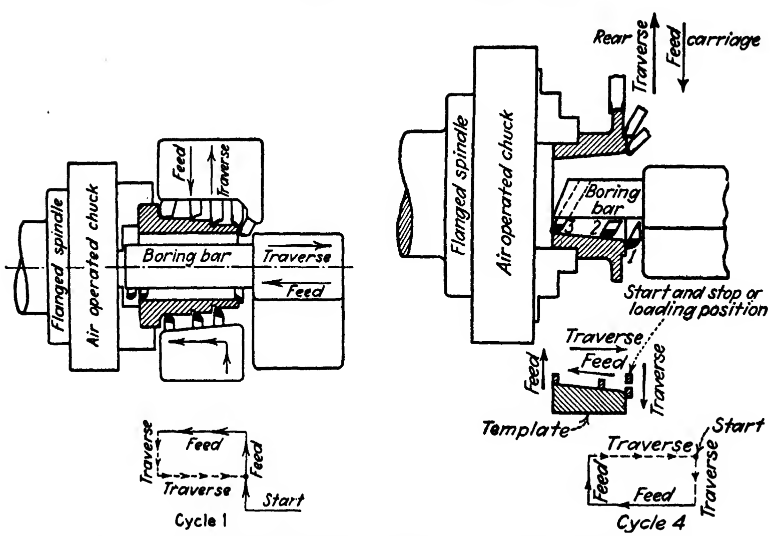


FIG. 135.—Two diagrams of tool layouts for boring and turning.

the controls are automatic. The operator puts in a piece of work, presses the "start" button on the control panel, and has

nothing else to do until the piece is finished so far as this operation is concerned. When the cut is completed the spindle stops, the flow of coolant is shut off, and the tool slides return rapidly to the starting point. After taking out the machined piece, a new one is put in place and the cycle repeated.

Sellers Wheel Lathes.—Lathes built especially for turning the tires on either car wheels, truck wheels, or driving wheels used in railroad work are known as wheel lathes. They are single-purpose machines but handle quite a range of sizes. A

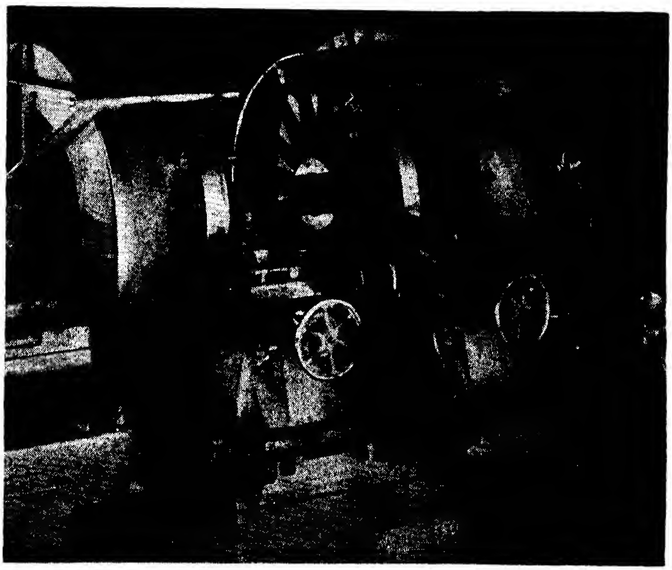


FIG. 136.—Sellers driving-wheel lathe.

driving-wheel lathe is shown in Fig. 136 with a pair of driving wheels in place. The massive construction of the lathe and the tool blocks should be noted. Gages for checking diameters are shown over each wheel.

A car-wheel lathe is seen in Fig. 137 with the wheel hoist as part of the machine. The headstock at the right moves back by power to take out the work and to put in a new pair of wheels, hence the roller supports over this head. The method of driving the wheels is seen in Fig. 138. The axle goes into a collet-type centering chuck in the hollow spindle, but the driving is done by dogs forced against the side of the tire. The driving jaws *A*

are forced against the wheel by means of the cam B, which is turned by the bolt head C. As an example of the way in which

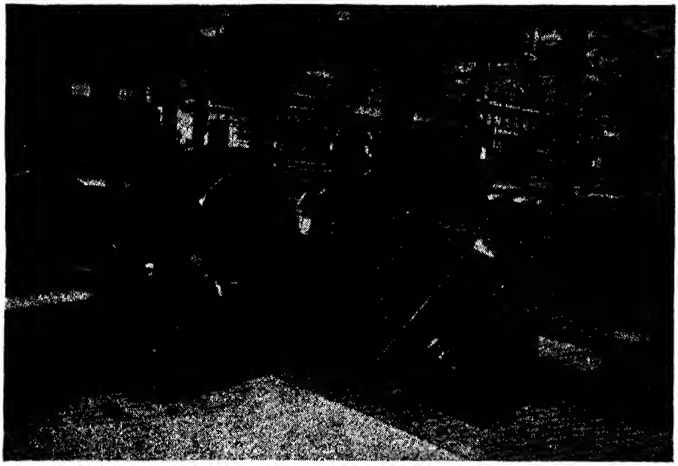


FIG. 137.—Sellers car-wheel lathe.

these lathes handle their work, 14 pairs of 42-in. wheels have been turned at the rate of 12 min. 54 sec. per pair. Both of these lathes are manufactured by the William Sellers Company.

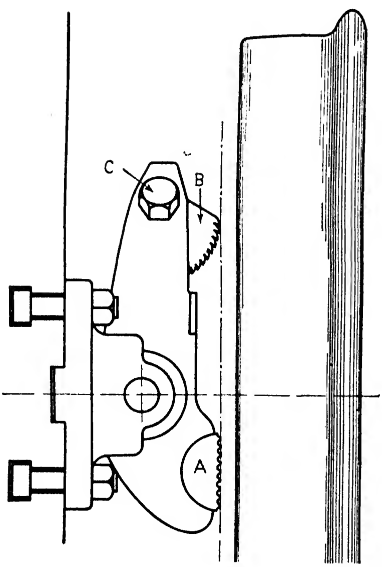


FIG. 138.—Dogs that drive the wheels.

LeBlond Crankshaft Lathe. The great demand for automobile crankshafts resulted in the design of special lathes for turning them. One of these lathes, built by the R. K. LeBlond Machine Tool Company, is shown in Fig. 139. The lathe turns all the crankpins on two shafts at the same time, or it can be turning one shaft while the crank cheeks are being faced on the other shaft. The work is held in hydraulically operated chucks, which hold and drive from each end. These chucks are inter-

locked with the motors so that the machines cannot be started until the chucks are locked on the work. Before turning the

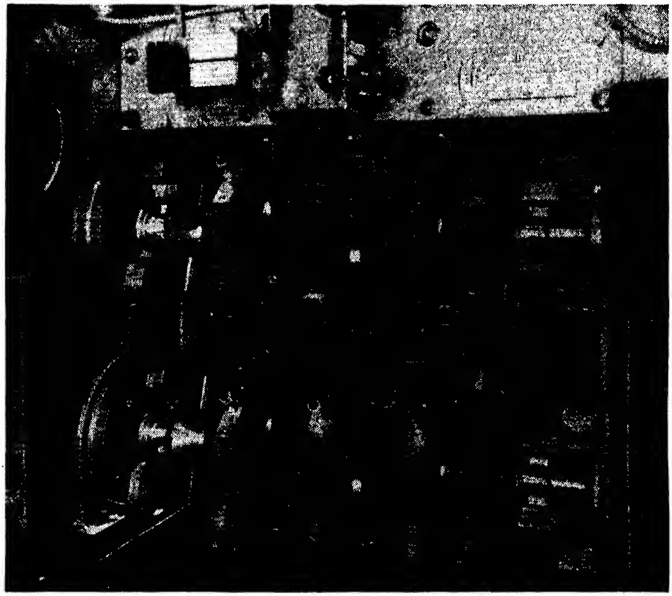


FIG. 139.—LeBlond crankshaft lathe.

crankpins or facing the crank cheeks, the main bearings are turned in another machine. This permits the steady rests shown to support the shaft at each central bearing, while the pins are being turned. The turning tools follow the crankpins as they turn in the steady rest bearings.

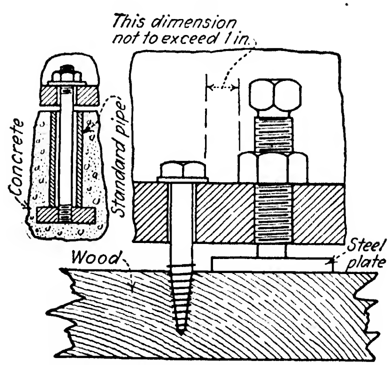


FIG. 140.—Westinghouse standard floor fastening for machine tools.

Fastening Lathes to the Floor. All machine tools that are to do accurate work must be fastened to the floor so as to be free from both bending and twisting strains. Many good machines have been damaged by bolting them down on an uneven floor. In order to prevent such straining of machines in places where

the floor may not be exactly level, the Westinghouse Electric & Mfg. Co. has adopted standard fastenings for different machines. Figure 140 shows the type of fastening for light machines, such as the average lathe, on either wood or concrete floors. The base flange of the machine, or the leg if it has legs, is tapped for the screw shown, this screw being close to the holes for holding the machine in place. There should be just room enough to use a wrench comfortably, 1 in. being allowed, as shown. A lag screw or bolt holds the machine down to a wooden floor, and a bolt sunk in the concrete, as shown in the small sketch, does the work in the case of concrete. The screw in the flange and the steel plate under it permit the leveling of the machine at any time if the foundation or floor should settle. This combination of hold-down bolt and leveling screw makes it easy to keep machines lined up without strain to the beds.

CRANKSHAFT OPERATIONS

So much heavy machinery such as large marine engines, Diesel engines, and allied units is being manufactured today that it forms a very important part of the output of the large machine shops. Many mechanics have had little opportunity to observe the methods of such plants, particularly where the bulk of the metalworking organizations in a community have been devoted principally to a more commonly manufactured type of equipment, such as automobiles, motors, implements, and small parts of various kinds. There is much to be learned from the methods of plants doing the heavy machine work necessary in the construction of engines and certain other kinds of large machinery.

Figures 141 and 142 are views of heavy crankshaft work for Diesel marine engines. The lathe in the foreground of Fig. 141 is a 36-in. swing tool raised to 42 in. capacity and having a 44-ft. bed. The lathe in the middle background is a 48-in. machine, and at the rear is a 72-in. lathe with a 44-ft. bed. All three lathes are shown on heavy six-throw crankshaft operations.

The close-up in Fig. 142 shows the finishing of the cheeks of crankshaft throws in a big lathe, with the swing increased by means of raising blocks. The shaft is mounted at the outer end in a special offset fixture that fits closely on the ends of the shaft journal. These offset devices have three centers exactly 120 deg. apart, and, when placed on the end of the shaft, they are mechani-

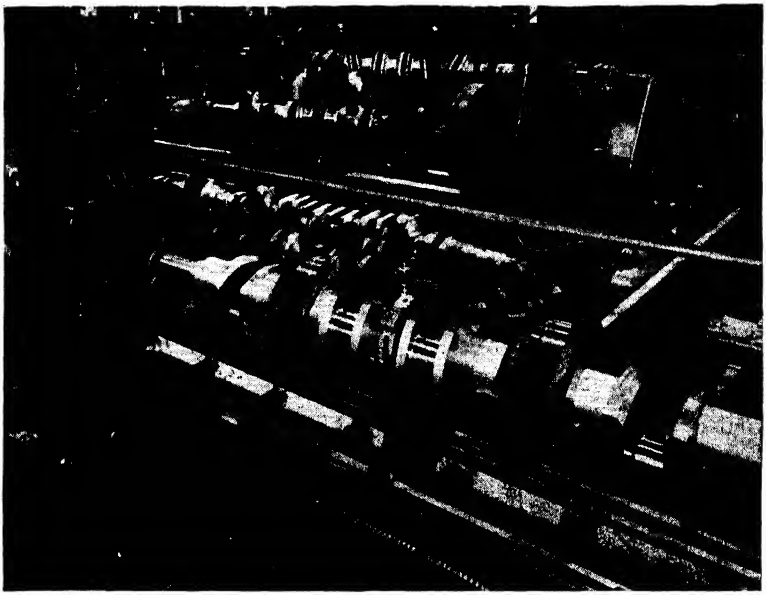


Fig. 141.—Turning a Diesel-engine crankshaft.

Fig. 142.—Special tool post for turning crank cheeks.

cally positioned to align precisely with their respective crankpin axes. The head end of the work is here shown with the coupling flange mounted against the faceplate on the spindle, where it is provided with means for setting in the three positions corresponding to the centers in the offset device at the outer end of the crankshaft.

The design of a tool post for machining crankpins and cheeks also is shown in this view, Fig. 142. The six-throw shaft illus-

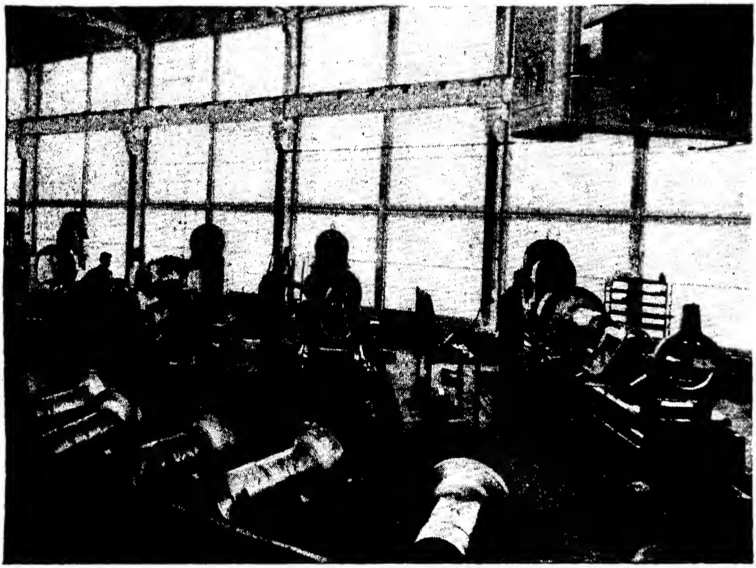


FIG. 143.—Short ends of built-up crankshafts.

trated in this photograph is 17 ft. long and has 9-in. journals and 8-in. crankpins.

Two views of departments at the Joshua Hendy Iron Works showing the turning of shafts and other work on triple-expansion marine engines are reproduced in Figs. 143 and 144. The first of these photographs shows short ends for built-up crankshafts, which are built up in three sections with webs and crankpins secured by shrink fits. This construction may clarify the study of Fig. 144, which illustrates a novel floor fixture (or set of fixtures) for crankshaft-assembly operations.

These massive pillow blocks are adjustable laterally on the bedplate of the fixture, and the crankshaft sections, turned to

size and with crankpins and webs finished, are mounted in the fixture blocks, which have special stop devices for gaging the locations of the three crankpins at 120-deg. angles with each other. When the webs are shrunk into position, holes are drilled half in the web and half in the crank end to receive large dowel pins. The equipment for this drilling operation consists of a portable tool developed especially for the purpose.

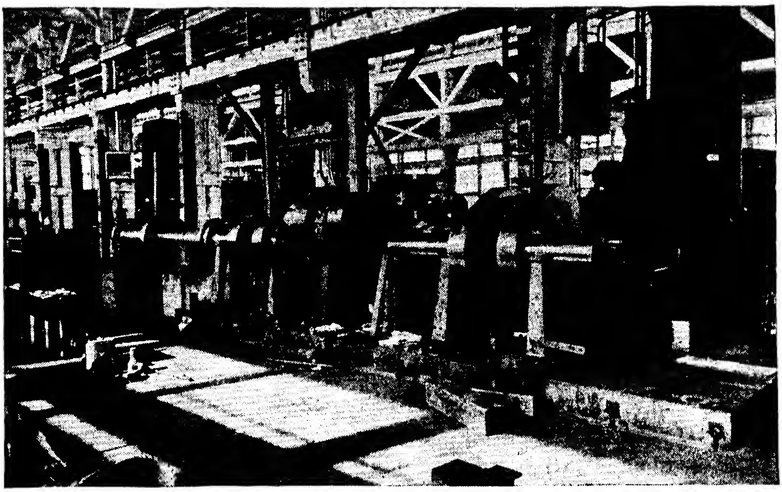


FIG. 144.—Assembling fixture for crankshafts.

It should be noticed that the crankpins are well lagged with wood to protect them against careless handling until the crankshaft is finally placed in its bearings in the engine under assembly.

SPINNING LATHES

Spinning is an old and simple process of forming sheet metal into cylindrical and similar shapes by forcing it over a form as the metal and the form revolve. A chuck or former of the desired shape is attached to the lathe spindle and the blank or disk of metal is held against the form by a support in the tailstock. This tail support is mounted on ball bearings so as to revolve freely with the metal to be spun.

With the metal revolving, a steel spinning or burnishing tool is applied, starting at the center, and the metal is forced against the form. This is usually done by hand, the pressure being

obtained by using a pin in the T rest that supports the tool. In this respect the process resembles wood turning.

Application of pressure against the disk causes it to assume the shape of the form itself and the flat disk becomes a seamless vessel or cylinder, similar to those obtained by drawing presses and dies. A good spinner can, however, produce a great variety of shapes with only the expense of the forms. These forms are usually of wood, if only a few pieces are to be made, but are often of metal, especially where the work is fairly deep.

Probably the majority of spinning forms are made from kiln-dried maple. After being bored and threaded to fit the lathe spindle, the blocks are turned to a templet which gives the desired form. If no sample is available, the templet is laid out from the drawing, care being taken to make allowance for the thickness of the metal. When many pieces are to be spun, the form is sometimes made of lignum vitae. Sometimes the form is turned small enough to allow a metal shell to be spun over it to bring it to the right size. This shell is then cemented to the wood and the spinning done over the metal cover. For continuous spinning the forms are made of cast iron or steel, which will, of course, give almost indefinite service.

Although the process appears simple, wide experience is necessary to obtain satisfactory results. This is especially true if a uniform thickness of metal is desired. Forcing the metal continuously in one direction will thin the metal. Skilled spinners control the metal flow to a remarkable extent by knowing when to move the spinning tool backward as well as forward. An experienced spinner can make work that will be elongated, or restricted, to a definite length and thickened at the end.

The extent to which metal can be formed depends largely on the kind of material and its thickness. Metal which work-hardens rapidly can only be spun, or deformed, a given amount before it must be annealed, after which further spinning can be done.

While the advances made in drawing sheet metal in the drawing press have largely replaced spinning where quantities warrant the cost of drawing dies, spinning is still a real business in nearly all industrial centers, and lathes for spinning are made by several concerns. One of these lathes, with a variable-speed motor

built into the headstock, is shown in Fig. 145. Most spinning lathes are, however, still driven by belting.

Thorough lubrication of the blank before starting to spin it and during the spinning operation is essential. Tallow, vaseline, lard oils, and mineral oils form the base of the lubricants used, a

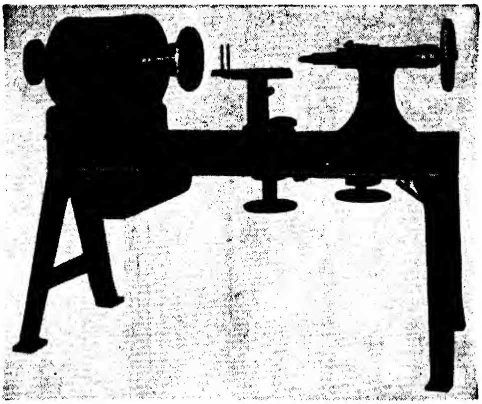


FIG. 145.—Fruin motor-driven spinning lathe.

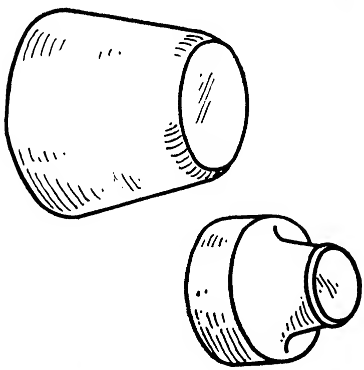


FIG. 146.—Two simple forms for spinning-lathe work.

great variety of lubricants being prepared from these materials. A combination of tallow and mineral oil, mixed to a semi-solid consistency, gives satisfactory results. The lubricant can probably be applied best with a brush.

Two rather simple forms used in spinning metal are shown in Fig. 146. The spinner, of course, begins at the center and works his tools out toward the outer edge. The deeper the object

to be spun the more care and experience are necessary, shallow objects being comparatively easy to form. The tools used in hand spinning are many and varied. Some idea of them can be had from Fig. 147, which shows the tools suggested by the Thomas Fruin Machine Company, who make both lathes and tools.

The action of the spinning tool on the sheet can be seen in Fig. 148, where *A* is the form, *B* the tail center, and *C* the metal sheet before the operation begins. As the spinner begins to work the tool *D* against the sheet, it assumes the shape *E*, and,

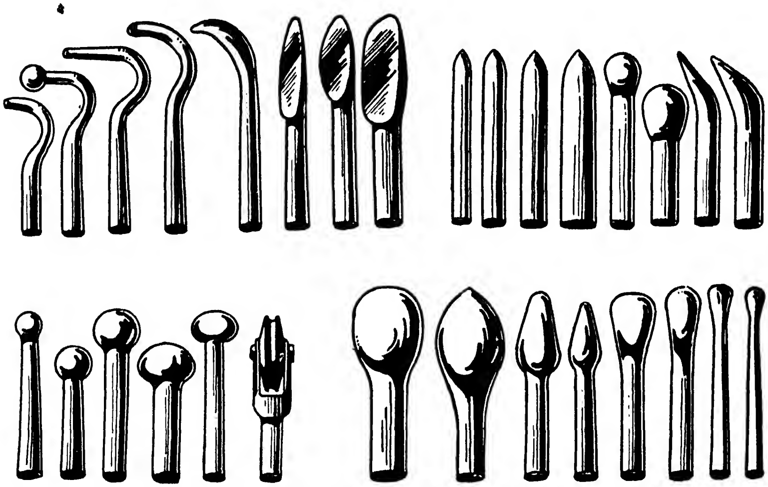


FIG. 147.—Types of spinning tools used.

as the tool forces the metal back, it works back to *F* and finally to the completed shape shown.

Where it is desired to spin pieces in which the mouth, or opening, is not the largest diameter or where the shape will not permit the withdrawal of the form, sectional or "split chucks" are used. These forms are built up in such a way that, after the spinning is completed, a central portion of the form can be withdrawn and the other pieces collapsed inside the work. The form is, of course, removed from the lathe spindle before this is done. As the pieces are removed they are reassembled on the center, or core, and held by some sort of a retaining flange. The reassembling takes very little time.

Such forms are usually made of wood but may be made of

metal if their use warrants it. The core and retaining ring are first made from one piece, and the outer portion that gives the required shape is turned in one piece that fits over the core. This outer piece is then cut into sections of such shape that they can be withdrawn easily, by using a fine saw. Radial cuts can be used on some of the parts only as it must be possible to withdraw at least one piece toward the center so the rest will collapse and be easily withdrawn from inside the work. It is frequently necessary to add a thin section to make up for the material removed by the different saw cuts, this piece being

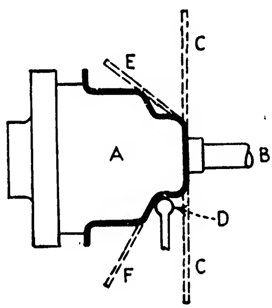


Fig. 148.

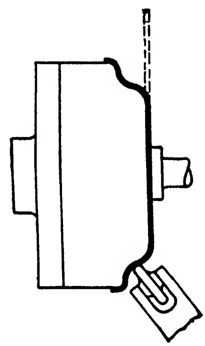


Fig. 149.

Figs. 148 and 149.—Action of tools that spin flat metal over forms.

called the "key." Oval work can also be spun by using an oval chuck in the same way as oval turning is done on an engine lathe.

Not all spinning is done with hand tools. Roller tools held in a slide rest are frequently used on some classes of work. Examples of this are shown in Fig. 149. By using a grooved forming wheel the edges of work can be curled over a wire or can be rounded without a wire inside.

Speed in spinning depends on the kind of material, its thickness, and diameter. The Fruin lathes are designed to run at 600, 900, 1,200 and 1,800 r.p.m. and the bearings to stand an end pressure of 2,000 lb. Higher speeds are not considered either desirable or safe.

Spinning of steel up to 6 inches in thickness is now being done by the Lukens Steel Co. This is however done on heavy boring mills or similar machines and is not a lathe operation. The plates are heated for this work.

Section II

TURRET AND SEMI-AUTOMATIC LATHES

CHAPTER VIII

THE TURRET LATHE

The modern turret lathe in its different forms is a development of the earlier hand-screw machine which in original type was designed for manufacture of small parts, such as screws and pins for pistols and other small products. It provided a means of making small duplicate parts much more rapidly than they could be turned out in the regular engine lathe and enabled special turning and other cutting tools to be applied to the work without necessity for changing them constantly as was the case with any tool used in the tool post of the lathe.

The revolving turret provided means for holding a series of tools, each in turn, being brought into alignment with the work and then giving place to the next tool as fast as its own cut had been accomplished. Later the development of the spindle collet and the "wire feed" enabled a long bar of steel or brass to be held in the spindle and fed through the collet as fast as each piece of work had been completed and cut off from the bar. Originally the stock that could be used in the spindle was quite small, hence the term "wire feed," as stated; the original purpose of the screw machine did not contemplate the possibility of machining parts of any appreciable diameter. But the old chucking system of holding the rod in the lathe chuck having been displaced by a collet chuck and then improved upon still further by the wire feed, it became apparent that larger work could be machined in the same fashion, if a hollow spindle was provided with enlarged capacity for receiving the stock and if general tool proportions and driving mechanism were increased accordingly.

The box tool made its appearance with early screw machines and was in fact the logical type of design for tools to be used in a turret holder. This is now used, with many modifications, some of which are shown in connection with the different turret lathes.

The simple hand turret machine led to the design of the automatic screw machine and at the same time was the forerunner of

a long line of heavier turret lathes which in different designs have been increased in capacities and in adaptability. They may be set up economically for even a small number of pieces and thus present the flexibility of the engine lathe. At the same time they enable production work to be handled in quantity with practically the same types of tools as used for a single or small number of parts.

Such machines are built for both bar stock work and chucking operations on castings, forgings, or work blanks cut from the bar. Chucks are supplied to suit any or all classes of work. Powerful drives and feed mechanisms, power feed for carriages and cross slides, power operation of turret with full and detailed control of speeds and feeds, all combine to provide practically complete mechanical operation of these machines, particularly in their heavier patterns.

In general such machines in the larger sizes are of two major types: the ram type where the turret is mounted on a sliding ram in an adjustable block on the bed; and the saddle type with the turret mounted on a form of carriage which operates the turret. In either type, according to size and design, the machine may or may not have a carriage corresponding to a lathe carriage, with cross slide to carry tool holders or turrets for a series of turning, or other tools. In the smaller machines—as with all of the earlier designs—the turret is carried on a ram or slide in its movable base block which takes the place of the usual tail-stock of an engine lathe.

Many of the types of turret tools used on the smaller machines are similar to the automatic screw-machine tools, in fact had their first use in the hand machines prior to the invention of the automatic machine. The portions of the chapter on automatic screw machines devoted to turret and cross-slide tools apply equally well to many types of hand-screw-machine and turret-lathe outfits. With the larger machines, tools of the more general form of regular lathe tools, boring bars, etc., are applied to both turret and cross-slide tool holders.

Automatic Turret and Chucking Machines.—The large sizes of automatic turret machines for cast iron and chucking work generally exhibit certain features of both automatic screw machines and heavy turret lathes. Cam operation of turret and tools movements is combined with the use of turning and facing

tools, boring and threading equipment and the like usually adaptable to a diversity of work in much the same way as the tool equipment of the turret lathe. These machines may also be supplied with magazine feeds for handling castings and forgings automatically. Similar provision is sometimes made with automatic screw machines, for feeding work to the spindle from a magazine instead of through the spindle collet, as with rod stock.

The Turret Lathe a General-purpose Tool.—The adaptability of the turret lathe has already been referred to. Receiving either bar stock through the spindle or castings or forgings in the spindle chuck, the tools mounted in turrets and on the carriage are applicable to a great variety of work with all the facility essential to rapid and accurate turning, facing, boring, threading, and other operations. For holding difficult shapes of castings special chuck jaws are used in which the work is secured as readily as symmetrical parts are gripped in the regular chuck jaws. Special tools and holders are readily developed for any specific purpose and applied as easily as standard equipment. Multiple tool holders increase the usefulness of this type of machine and are applicable to many classes of production jobs, to advance output over simpler tools used for small runs of work.

THE FLAT TURRET LATHE

The flat turret lathe, designed and built by the late James Hartness over 40 years ago, was a marked departure from previous practice. Instead of the usual turret, this had a turntable or horizontal faceplate, of large diameter, to which tools of various kinds could be bolted. One of the latest machines of this type is seen in Figs. 1 and 2, fitted with a special taper attachment for turning locomotive frame bolts. Some of the details of the tool set-up for this job can be seen in Figs. 2 and 3. While this tooling is special for this job, except for the taper-guide bar at the top, much of the tooling is similar to many other set-ups for plain work.

The forging is held in the air-operated chuck, the first operation being to point the end by the single blade in the coned tool holder shown in both Figs. 2 and 3. The turret is then indexed to the second position for turning the tapered body diameter and the straight portion for the thread. In turning the taper both

the tool slide and the supporting rolls are controlled by the taper former that follows the guide bar, which is pivoted to the head-

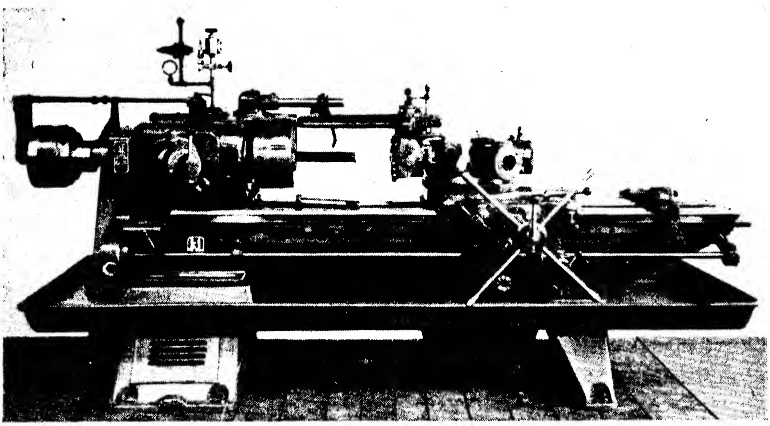


FIG. 1.—Jones and Lamson turret lathe.

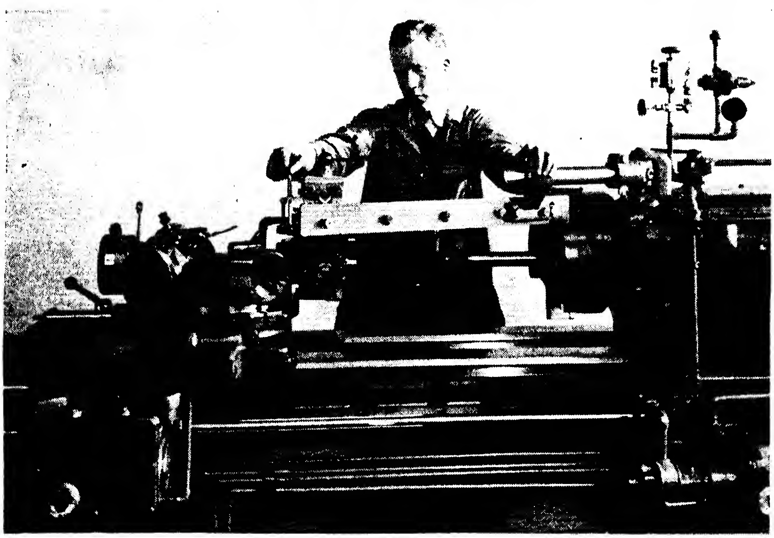


FIG. 2.—Details of the taper attachment.

stock. The crank mechanism adjusts the tool and rolls and the graduated dial permits readings in thousandths of an inch. The guide bar also carries a 24-in. scale which makes it easy to

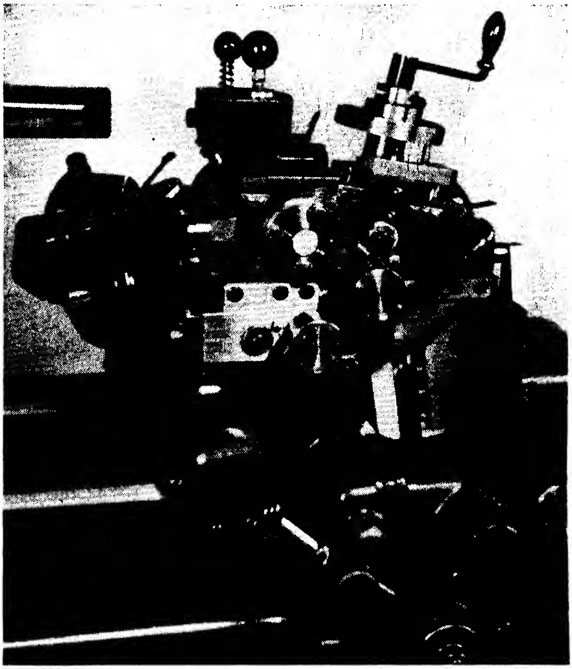


Fig. 3.—Pointing tool and roller back rest.

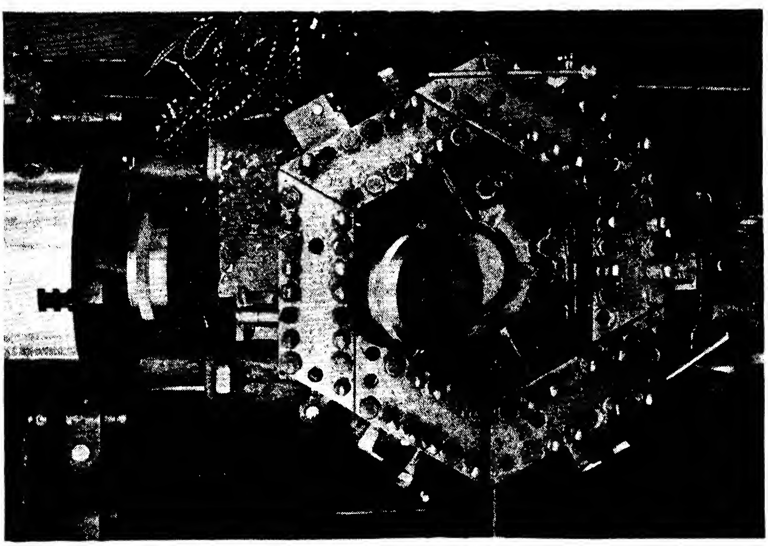


Fig. 4.—Turret tooling for cross-movement of headstock.

gage different lengths as required. The construction of the roller guides and the tool block can be seen in detail in Fig. 3.

Some of these machines have a cross movement to the headstock which makes possible two tool movements, this being quite desirable on some classes of work. These two movements, in connection with the large diameter of the turret, make it possible to use very complete tool set-ups as can be seen in Fig. 4. Each side of the large hexagon turret that is built up of tool holders bolted to the flat turret beneath carries tools for use in two positions of the headstock. This can be seen by noting both the facing and the boring tools close together in two of the blocks. A similar combination is possible where the same block carries a cut-off tool and a set of knurls. With the lathe headstock moved to the front the knurling shown on the work is rolled into the work. Moving the headstock backward brings the cutting tool into play and separates the piece from the bar or tube. The combination of the two movements makes possible a great variety of operations.

BORING DEEP HOLES

The Warner & Swasey Co. has increased its rate of boring lathe spindles 300 per cent by a careful study of chucking tools and lubrication. The holes vary from less than 1 in. to 4¾ in. in diameter and up to 40 in. in depth.

The small end of the spindle is held in a chuck with the outer end running in a roller-steady rest, as shown in Fig. 5. This figure also shows the boring tool, the guide through which it is fed, and the rest that supports the guide and the drill. Details of the drill may be seen in Fig. 6. This is made from flat bar stock, and the general shape, the serrated cutting edges, and the chip space are clearly shown.

The spindles are forged from S.A.E. 1050 or S.A.E. 4140 steel and have a Brinell hardness of 200 to 225. Cutting speed is 55 ft. per minute; feed is 0.008 in. per revolution. Cutters are ground after each spindle, each grind removing about 0.005 in. and thus keeping the drills in top condition.

Lubrication is important; about 45 gal. per minute are pumped through the bar at 250 lb. pressure. There are two extra streams of oil pumped on the outside of the bar to help to conduct heat from the drill. The oil contains a high percentage of sulphur and

saponifiable matter and has had high-pressure treatment. It has a Saybolt Universal viscosity of 140 sec. at 100°F.

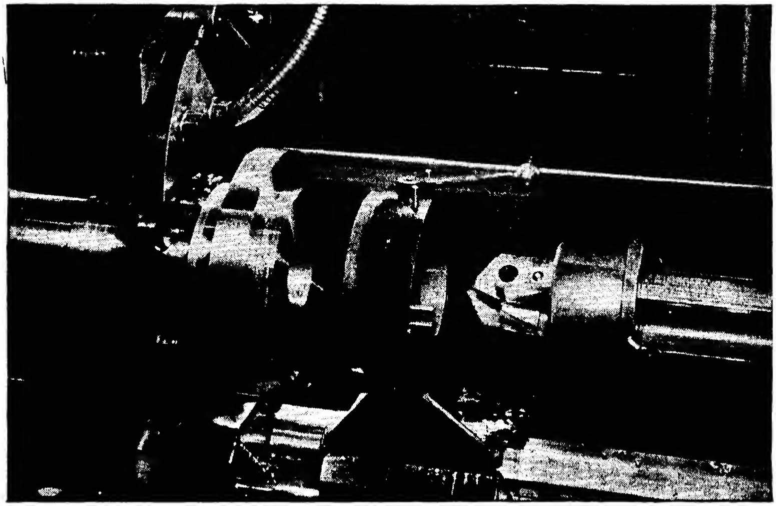


Fig. 5.—Deep-hole boring in lathe spindles.

After drilling, a shell reamer with a feed of ½ in. per revolution and a cutting speed of 40 ft. per minute is used. Only 0.020 in. on

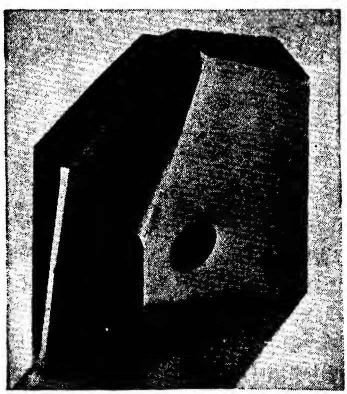


Fig. 6.—Detail of the cutter in end of boring bar.

the diameter, or 0.010 in. on a side, is left for reaming. Boring and reaming take about 2 hr. on an average-sized spindle.

CHAPTER IX

OTHER MODERN TURRET LATHES

JONES AND LAMSON UNIVERSAL RAM-TYPE TURRET LATHE

The Jones and Lamson new universal ram-type turret lathe is shown in Fig. 7. The machines are of completely new design and have many new productive features. They are built in two sizes—1½-in. and 2½-in. bar capacity.

The fundamental purpose of this new design is to permit the use, at the highest efficiency, of the latest types of carbide

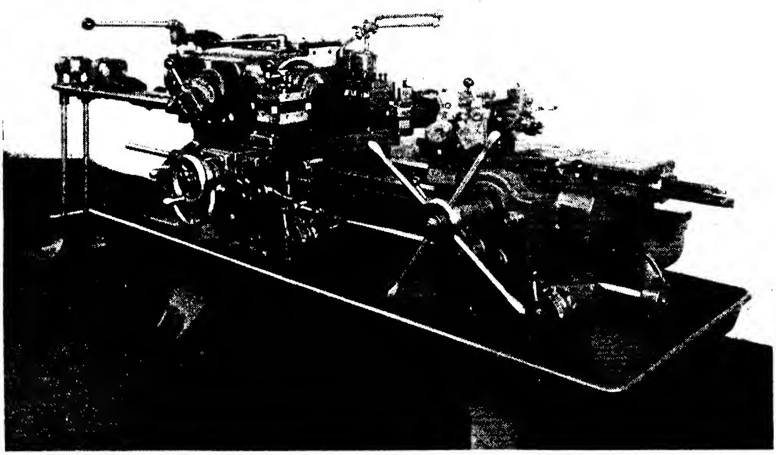


FIG. 7.—Ram-type turret lathe.

cutting tools with ample margin for future developments in that field. At the same time there are combined in the same machine all the factors of mechanism, convenience, and accuracy necessary to perform ordinary turret lathe operations with ordinary tools at the highest available degree of efficiency. This combination of purposes is needed in a turret lathe suited to present conditions.

The Headstock.—A single-lever dial selector controls all speed changes. One lever controls the forward and reverse motion of

the spindle and when it is moved to the neutral position an adjustable brake for stopping the spindle is automatically applied. The forward and reverse clutches and the brake are of multiple-disk type.

The machine has twelve selective forward and reverse spindle speeds, two ranges of which are standard equipment, namely: 20 to 1,000 or 40 to 2,000. This range covers the requirements of all cutting tools from carbon steel to carbide. All shafts are mounted on antifriction bearings. The gears are made from a high grade alloy steel, hardened and ground. The sliding gears are mounted on splined shafts. All headstock gears are ground in the tooth form and run in a bath of oil. The complete headstock is lubricated with a splash and filter system, and a visible oil level gage is located on the front of the headstock.

The main spindle is made from an alloy-steel forging and is mounted on precision ball bearings set up under a predetermined load. It is equipped with an 8-in. flange with a taper pilot.

All electrical equipment is mounted on the machine and wired to a control panel located on the front of the headstock.

Two types of driving units are standard: a flange-type motor mounted integrally with the headstock, or a motor mounted in the cabinet leg with the drive through multiple V belts.

Construction of Bed.—The bed is a double-box-ribbed casting of very rigid construction. Shoulders running the entire length of the bed are machined accurately to support and align the headstock and the hardened ways. The ways are of steel, carburized, hardened and precision ground. They are attached to the bed with vertical and angular cap screws spaced 4 in. apart. The hold-down screws enter blind tapped holes in order to provide an uninterrupted bearing surface for the carriage and saddle.

The carriage and saddle alignment are taken against the vertical sides of the front way and gibbed with adjustable taper gibs. The hold-down gibs for the carriage take a bearing on the under side of the hardened ways. Leveling screws are provided in each leg of the machine.

Carriage Details.—The carriage is of the universal bridge type and is made exceptionally heavy for support of the many tools that may be in operation at one time. T-slots in the front and rear of the carriage cross slide provide for multiple tooling.

Standard equipment includes a square turret on the front (Fig. 7) and a dovetail tool slide on the rear. The square turret is controlled entirely by one lever. Each turret face is drilled so that a multiple tool block, with a capacity of four tools, can be mounted on each face.

Maximum multiple tooling for rear mount tools may be attained by means of dovetail tool blocks fitted to the tool slide.

The carriage apron is equipped with a sliding-gear transmission for nine variable longitudinal and cross feeds, all controlled with a single-lever dial selector. All feeds can be changed while the machine is running. The range of feeds for longitudinal travel is from 0.005 to 0.100 in. and the cross-feed range is from 0.0025 to 0.050 in. per revolution of the spindle.

The carriage and the ways are automatically lubricated by a force feed pump incorporated in the apron. All gears run in a bath of oil. The shafts in the apron are mounted on antifriction bearings. The gears are made from a high-grade alloy steel, hardened and ground. The sliding gears are mounted on splined shafts.

The carriage is equipped with a spool stop (Fig. 8) for longitudinal feeds and an adjustable stop bar, also a spool stop for the cross feed with adjustable stop dogs which will disengage the feed in either direction.

The feed for the carriage is automatically disengaged as the carriage comes in contact with a stop, or it can be manually tripped. The feed knockoff is against a positive stop. The apron is provided with a feed-reversing lever. A safety friction clutch is incorporated in the apron.

For turning or boring tapers a standard taper attachment is bolted to the rear of the carriage. A thread-chasing attachment, installed on the carriage apron, is also standard equipment.

Ram-turret Saddle, Slide, and Apron.—The machine is fitted with a hexagon turret with all faces bored, counterbored and drilled for mounting standard bar and chucking tools. It is indexed from one position to the next with a star wheel. The turret is equipped with an automatic clamp ring. On the return movement of the slide the turret is unclamped, indexed to the next position and on the forward motion automatically clamped. It is equipped with six adjustable stops.

A manually operated lever on the front of the saddle disengages the indexing mechanism so that the turret can be indexed by hand in either direction.

The turret slide is of rigid construction for heavy-duty work and has hardened strips, or bearing plates, adjustable taper gibs for side adjustment, and hardened hold-down gibs. The apron for the turret is similar in construction to the one used for the carriage and is equipped with nine variable feeds all controlled

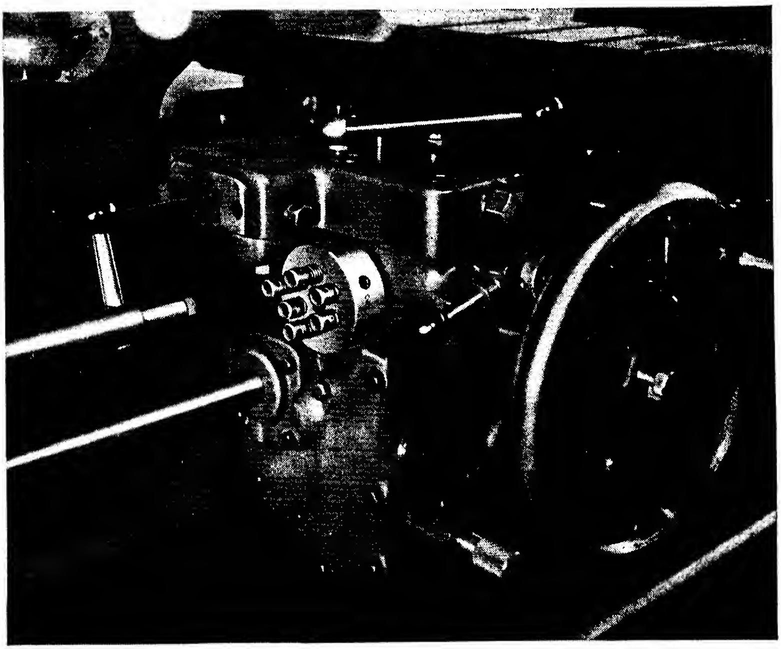


FIG. 8.—Adjustable stop bar and spool stop.

with a single-lever dial selector. The range of feeds is from 0.005 to 0.100 in. per revolution of the spindle. All gears run in a bath of oil, and a force feed pump, which lubricates the turret slide and saddle, is incorporated in the apron. The feed on the turret is through a rack and pinion. A feed lever is automatically disengaged as the slide comes in contact with the stop, or it can be manually tripped.

The cutting coolant is piped to the turret through the center pin and is distributed automatically to each turret face when

indexed to cutting position. All compound can be shut off with a lever conveniently located on the front of the machine. Suitable splash guards are supplied.

Bar Chuck and Tool Equipment.—The collet chuck (*A*) Fig. 9 has a master collet fitted with removable jaws for different sizes and shapes of stock. The bar feed mechanism permits the operator to stand at normal operating position, unlock the collet chuck, feed bar through the spindle, clamp the collet chuck and, while the machine is running, ratchet the stock carrier back for another series of feeding operations—all by the use of a single lever.

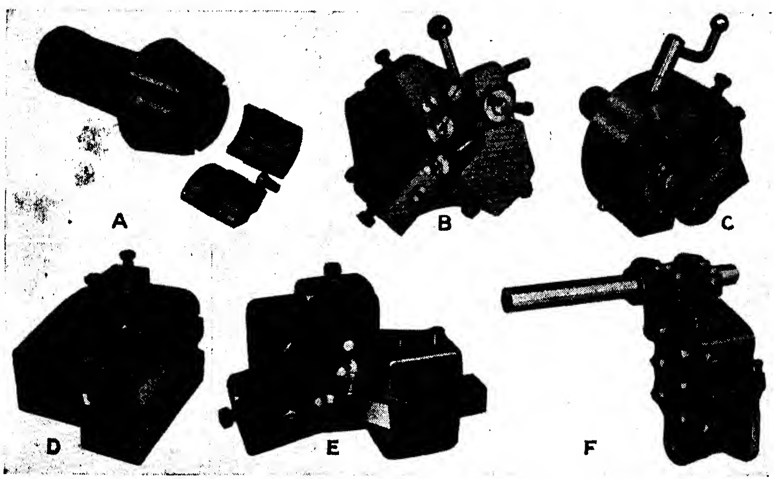


Fig. 9.—Bar chuck and tool equipment.

Some of the turret and cross-slide tools are shown in the illustrations. Thus at *B*, Fig. 9, is seen a roller back-rest turner which has hardened and ground rolls and studs held in adjustable carriers. The tool is in a swivel block which comes against an adjustable stop; the block is clamped tight while turning. The tool can be set either ahead or behind the rolls.

The quickly adjusting centering tool *C* has three rolls which are centered and operated by one lever for size adjustment. This provides quick adjustment for slight variations in diameter or change from one size to another.

A multiple-roller back-rest turner *D* has a tool plate for holding several tools so that more than one diameter can be

turned at the same time. On the rear side of the holder are two tool-carrier blocks which are adjustable lengthwise to take care of varying lengths of work. The roll carriers are independently adjustable for diameter and have hardened and ground rolls and studs similar to the other turners.

Special Tools.—The pointing tool *E*, Fig. 9, is for pointing, chamfering, or forming the ends of bar stock. The rolls are

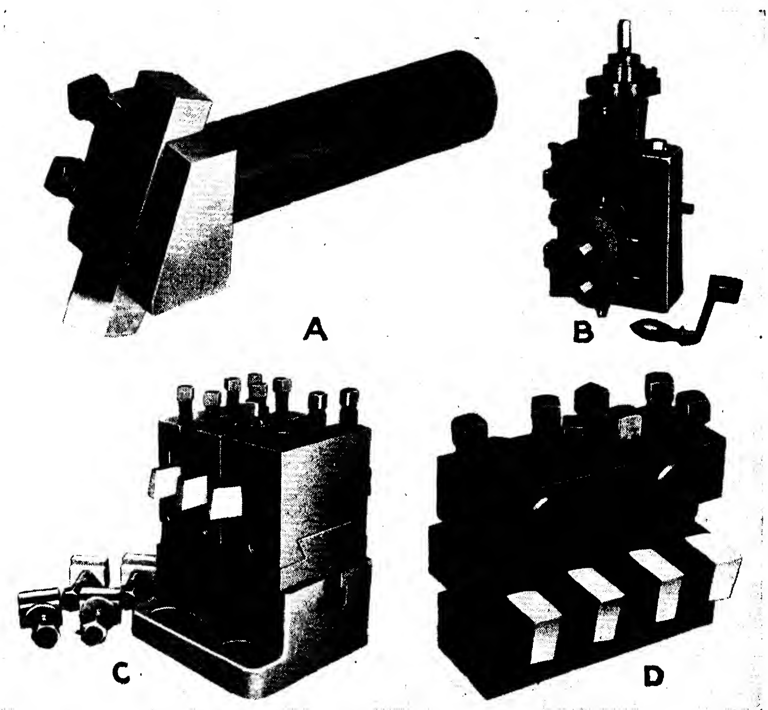


Fig. 10.—More of the tools used.

chamfered so that when pointing rough stock to facilitate starting a roller turner, the stock takes a bearing on the chamfer of the rolls.

A multiple-turning head *F*, Fig. 9 is used on work where a number of multiple cuts are taken in the same turret position. The holes are spaced so as to take care of a large range of work. In addition to being bolted to the face of the turret, the head

obtains added support by means of two jack screws on the top of the turret.

In Fig. 10, *A* shows an adjustable cutter holder, similar in general type to others for this turret with either straight or angle-cutter position. This holder is for use in the multiple-turning heads where very accurate diameters are wanted.

Figure 10, *B* is a slide tool for boring, recessing, and facing operations. Standard cutter holders or boring bars may be held in either of the holes or both. The slide has a micrometer dial for accurate adjustment.

A dovetail tool-block mounting for the rear of the cross slide is shown at *C*, Fig. 10. This provides for a rapid set-up of tools for chamfering, facing, and forming. A multiple-tool block for the square turret on the carriage is illustrated at *D*. The turret is made from a solid block of steel and is carburized and hardened. The multiple-tool block can be bolted to any face of the square turret. These blocks allow for the use of as many as four tools on any one face of the square turret, thus permitting multiple tooling without special tool blocks.

WARNER AND SWASEY MACHINES

Reference has been made to both saddle-type and ram-type turret lathes. An illustration in Fig. 12 herewith represents a Warner and Swasey sliding-saddle-type machine with universal carriage and all-geared head. Figure 11 shows a ram-type electric-turret lathe by the same builders and with a new design of head in which an inbuilt four-speed reversing motor is used. This machine is rated at $\frac{5}{8}$ by 4-in. capacity with a swing over the bed of 11 in. There is a single shift for starting, stopping and reversing the drive. There are no gears, the spindle being the only running member. The machine is built for high speeds for use with modern cutting tools, the range of four speeds being from 600 to 3,600 r.p.m. The spindle runs in antifriction bearings. When the machine is put into neutral, a brake is automatically applied. A new type of bar feed is used, and the work runs smoothly as the bar is centrally controlled. Even at high speeds the length of stock produces no whipping effect or vibration of spindle or work.

Types of Chucks.—Methods of holding work are of first importance in any turret lathe as well as in all other types of

machine tools. Besides collets for bar work the Warner and Swasey machines can be supplied as required with different types

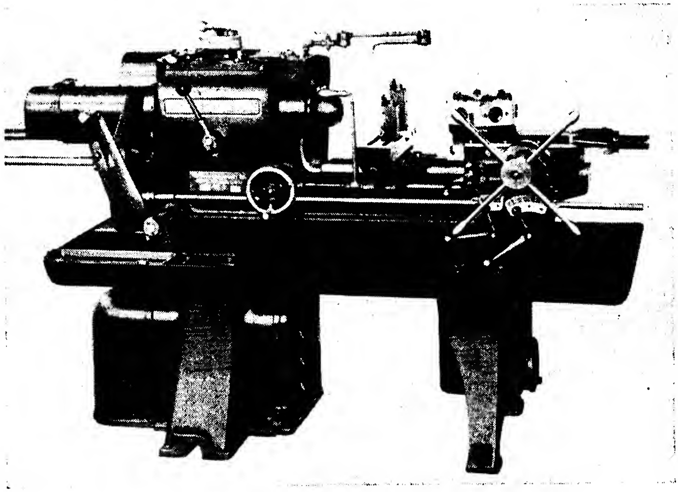


Fig. 11.—Warner and Swasey ram-type turret.

of chucks—for castings, forgings, etc., among them the regular wrench-operated chuck with two, three, or four jaws, or the universal three-jaw chuck; the air-operated chuck where air

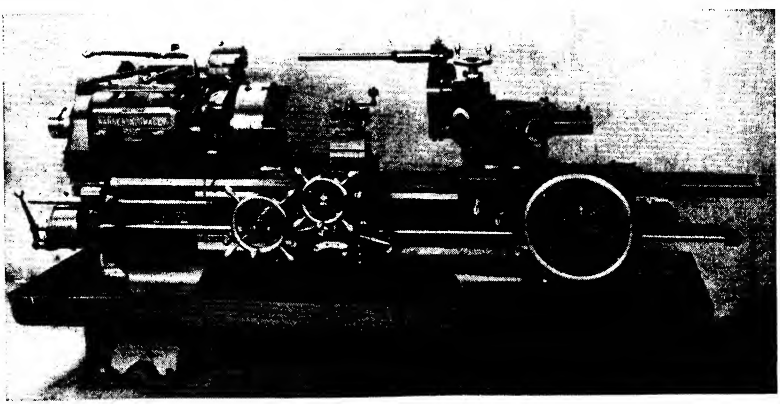


Fig. 12.—Saddle-type lathe by same builders.

with pressure from 60 to 100 lb. is available; and the wrenchless chuck which is also a quick-acting device somewhat less expensive to install than the air chuck.

Chuck jaws for long work or for awkward castings are important for many jobs that are to be handled on the turret lathe. Typical jaws of this kind are shown in Fig. 13.

The solid jaws at *A* are fitted directly into the chuck proper and do not have the removable feature. These jaws are used where cut is started at a distance from the chuck equal to more than one-half the chuck diameter. In the set-screw jaws at *B* the work is located at the back end by the jaw and the free end is gripped with the set screws. This type is rigid for long work

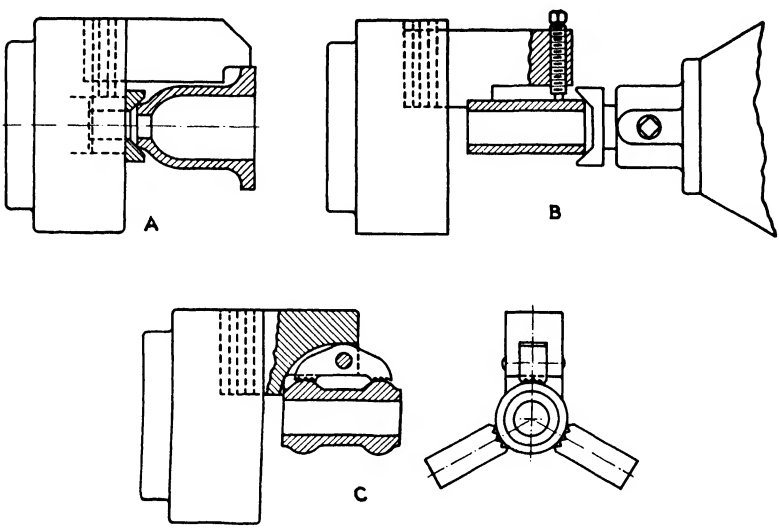


FIG. 13.—Types of jaws for awkward work.

and not too expensive. Both jaws *A* and *B* are stronger for long work than removable jaws which normally are fastened by screws to the jaw bases proper.

A "rocking" jaw is shown at *C*, Fig. 13, which is used on long work where there are slight variations in diameter to be allowed for in the rocking of the jaw about the pivots. One jaw of this type is used together with two solid jaws in the same set.

Example of Bar Work.—The automobile fan shaft Fig. 14 is an example of bar work with several diameters and shoulder distances, produced in quantity lots. A study of the drawing suggests "combined cuts" for turning diameters 2 and 5, shown in the tooling layout in Fig. 15 so the piece is put on a machine

with a universal type of cross slide. The turning length of the shaft is short, which allows the use of a ram-type machine, and the size of the shaft requires a $1\frac{1}{2}$ in. capacity turret lathe.

The piece is turned ready for grinding, so that the finish on the diameters does not need to be very smooth. A multiple cutter turner with the rollers riding on diameters 3 and 5 is

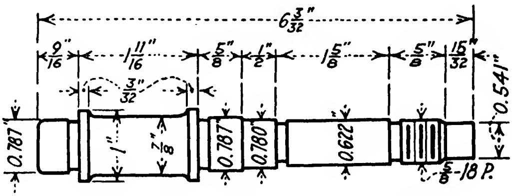


FIG. 14.—Bar work done on turret lathe.

therefore used for turning diameters 3, 4 and 7, thus applying the principle of "multiple cuts" to the finish turning.

Another application of the same principle is the use of a standard necking tool, mounted at the rear of the cross slide, for taking the four necking cuts at one time. This is done while the shaft is supported by the center in the hexagon turret.

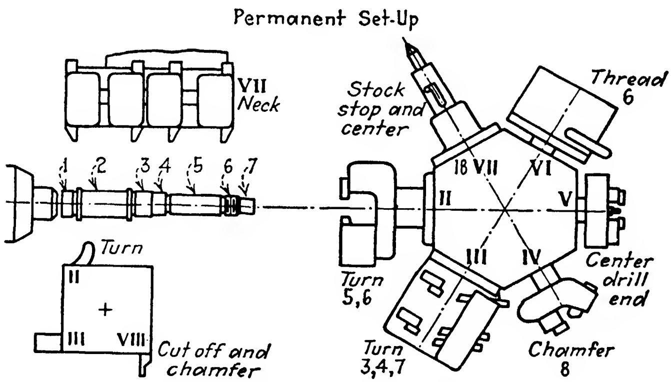


FIG. 15.—Tooling layout for fan shaft.

The tool has provisions for the adjustment of the various blocks for different jobs.

The tooling layout shows the turret faces numbered to correspond with the order of operations. For example, cutter II in the square turret is turning at the same time tool II is turning in the hexagon turret.

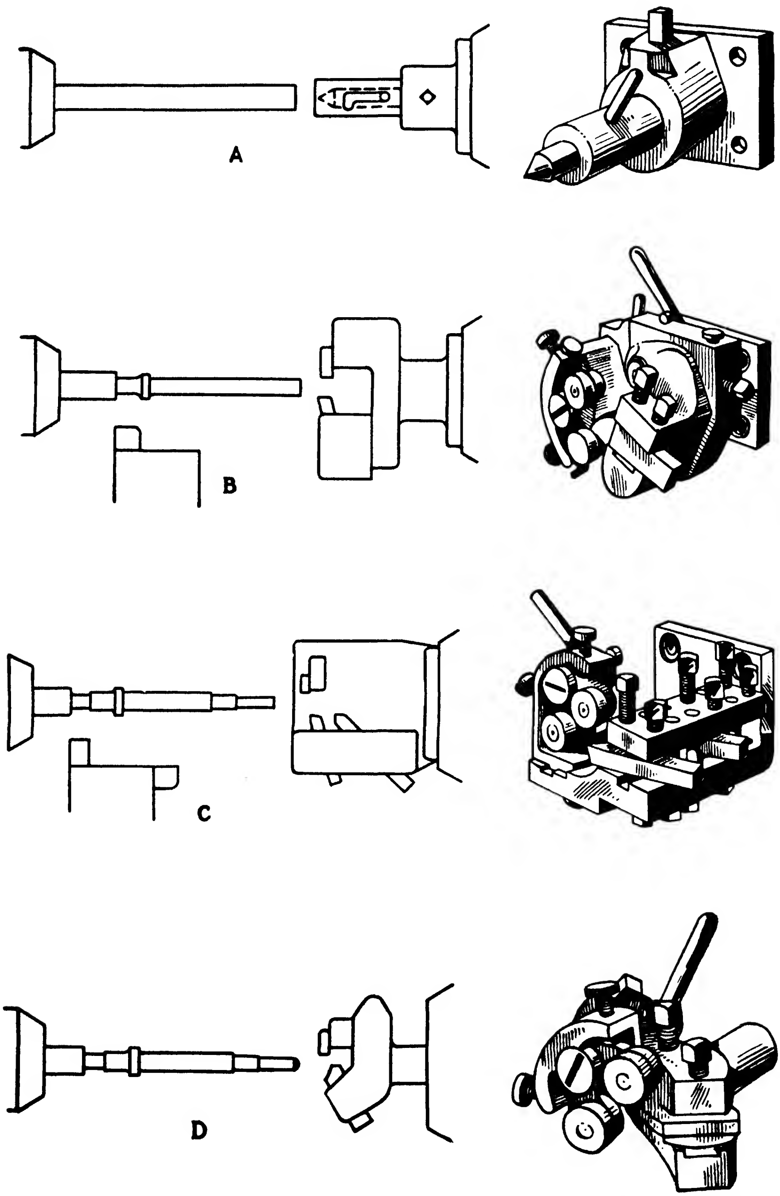


FIG. 16.—Tools for bar work. *A*, combined stop and center; *B*, roller back rest and cross-slide tool; *C*, another form of roller tool; *D*, support for facing end of shaft. (*Continued on following page.*

Universal Equipment for Bar Work.—The universal set of bar tools is shown in more detail in Fig. 16. The set illustrated is for a 1½-in. turret lathe, and will handle the greater part of the work within the cutting range of the machine. Similar sets may, of course, be developed for other sizes of machines.

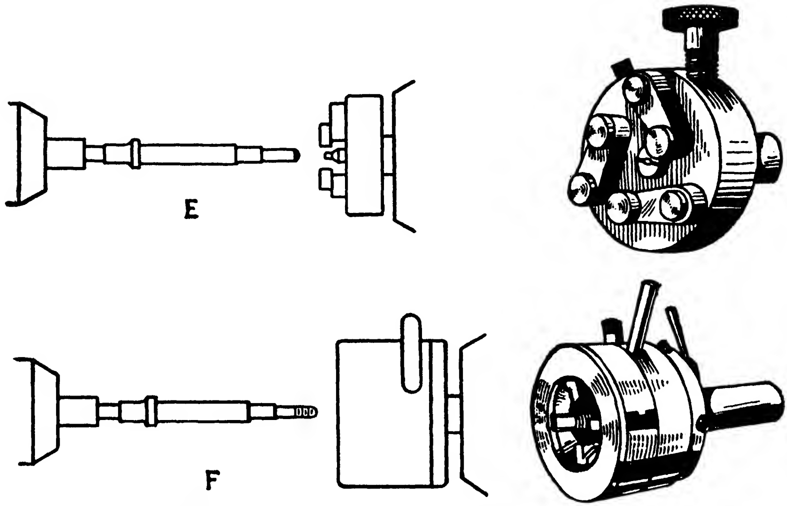


FIG. 16 (*Continued*).—Tools for bar works. *E*, center drill with roller support; *F*, releasing threading die.

Simple diagrams of the individual tools are also given so that they can be used when planning actual tool layouts. Operators do not always have a thorough grasp of the principles of tooling, and as a result their set-ups may be only partly correct.

By preparing a simple layout first, the best combination of tools can be easily determined and permanently recorded. These individual tool diagrams may be used in making such layouts by tracing them on tracing paper. Blue prints may then be made quite similar to those used for other kinds of work.

The universal equipment for bar work will perform operations efficiently on all classes of bar work within the range of the machine for which it is intended. Even in quantity production such equipment often equals the performance of special tools developed for quantity production and naturally its cost is considerably less. Six examples are given in *A*, *B*, *C*, *D*, *E*, and *F*. These begin on the preceeding page.

Chucking Work.—The variety of work made from bar stock in such machines is very great, but chucking work is handled

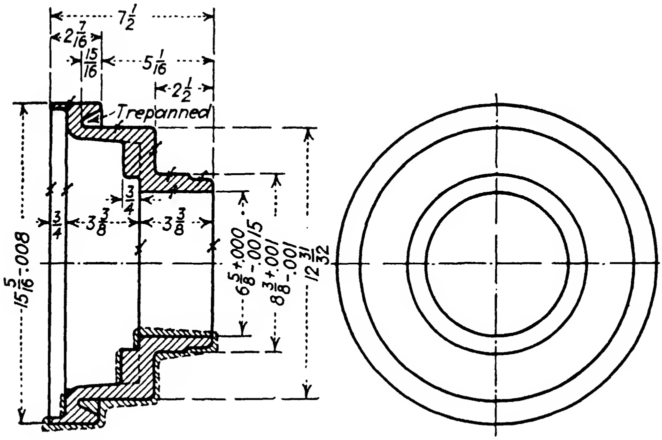


FIG. 17.—A typical piece of work.

in even wider variety. Typical of such work is the piece in Fig. 17, shown in the chuck in Fig. 18.

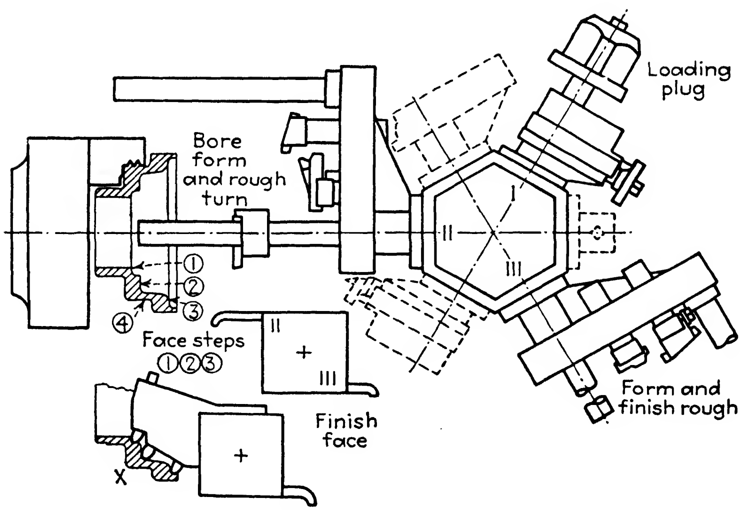


FIG. 18.—Tooling layout for work shown.

The rough drop forging for this piece is about 16 in. in diameter and weighs 116 lb. About 30 lb. of stock must be removed, so

that sufficient power must be obtained to pull deep, multiple cuts from the hexagon turret, with a feed of 0.035 in. Hence, a large sliding-saddle type of machine is used with both overhead and center pilots to give extreme rigidity.

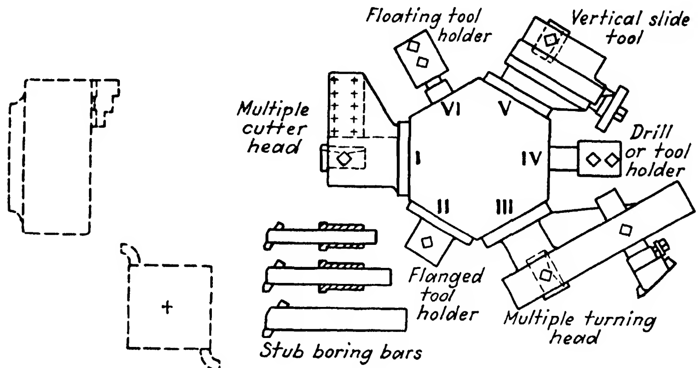


FIG. 19.—Tools without overhead pilot.

The first chucking grips the commutator shell on diameter 4 with hardened and corrugated jaws. These jaws are of the solid type, due to the considerable overhang. In the second chucking soft removable top jaws can be used because of less

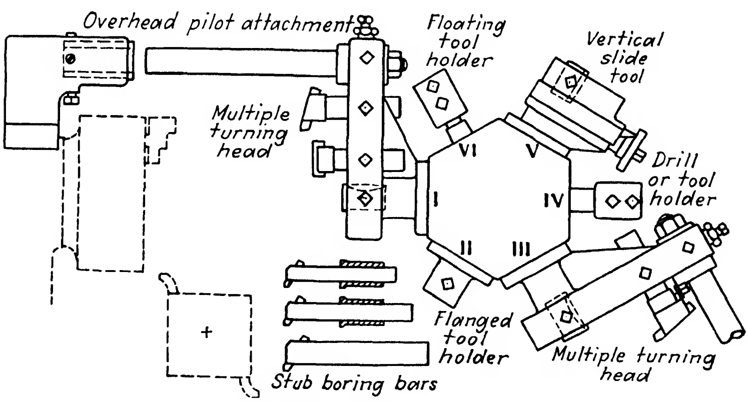


FIG. 20.—Overhead pilot bars in two stations.

overhang. Since the hole must be concentric with the V groove, a rough boring cut to relieve the metal is taken in the first chucking. The finishing cuts are therefore taken in the second chucking.

This job, as described, is done in lots of one hundred pieces; therefore, the inside faces 1, 2, and 3 are machined with a simple forged cutter held in the square turret. If larger quantities are to be produced, a special tool holder mounted in the square turret might be used as shown in the lower part of the layout.

In general, the two sets of tools used for different varieties of work on this make of machine are the plain set of chucking equipment and the overhead pilot set. The tools in Fig. 18 are used with overhead pilot. A good comparison of the two sets is presented in Figs. 19 and 20. Both sets are for the 16-in. ram-type turret lathe. Similar sets are made for smaller and larger machines. The differences in the overhead set from the plain are shown in bold-face type in this list.

Plain Set	Overhead Pilot Set
1. Multiple-cutter head.	1. **Multiple-turning head with overhead pilot bar and bracket.**
2. Flanged-tool holder.	2. Flanged-tool holder.
3. Multiple-turning head without pilot.	3. Multiple-turning head **with overhead pilot bar.**
4. Drill or tool holder.	4. Drill or tool holder.
5. Vertical-slide tool.	5. Vertical-slide tool.
6. Floating-tool holder.	6. Floating-tool holder.

GISHOLT TURRET LATHES

Gisholt lathes have been materially changed in design and construction. Headstocks are now cast integrally with the bed in all cases. Other features vary with the machine size and purpose and include cross-feeding turret, thread-chasing attachment, taper attachment for the turret, automatic indexing of the square-tool post, automatic clamping of the turret to its seat, and other devices. The ways are flat and of hardened steel, ground in place. One of the larger machines, which swings 39 in. in the gap, is shown in Fig. 21. This also shows how a large gate-valve body is held in a fixture that can be indexed in five positions. The weight of the fixture and the valve body is 2,325 lb., which gives some idea as to the stiffness of the spindle and the general rigidity of the machine. Still another example of heavy turret work is seen in Fig. 22. It will be noted that, while the tools in the turret make it appear top-heavy, there are two pilot or guide bars that insure alignment at all points of the turret travel. One pilot bar enters a hardened and ground

bushing in the hollow spindle and the other a similar bushing at the top of the headstock.

Cross-feeding Turret.—The advantages of the cross-feeding turret slide are seen in Fig. 23, where the work is being bored by a

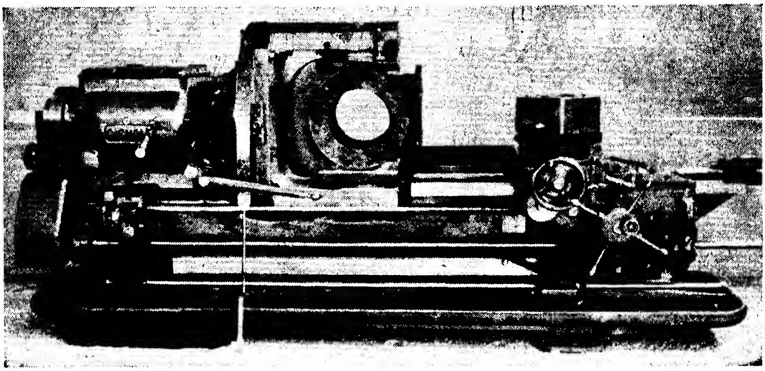


FIG. 21.—Large gate-valve body in Gisholt lathe.

single-point tool. At the same time the turret carries two long, piloted bars fitted with boring cutters, for certain portions of the job. The square, four-position tool post enables the outside to be turned with any sort of tool desired, just as in an engine

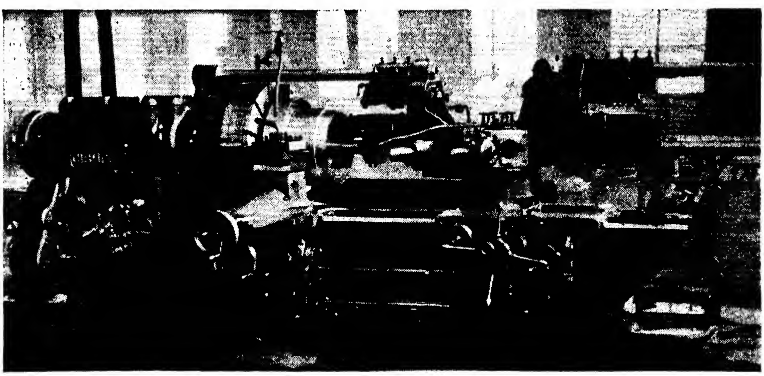


FIG. 22.—Tool layout for a large job.

lathe. Cutting lubricant can be forced to every tool. The spindle and the head gearing are shown in Fig. 24, illustrating the use of plain spur gears, helical gears, roller chain, and V-belt drive, as well as numerous ball and roller bearings. The turret

indexing and clamping mechanism is seen in Fig. 25, this being a turret having a cross movement. The bevel pinion which

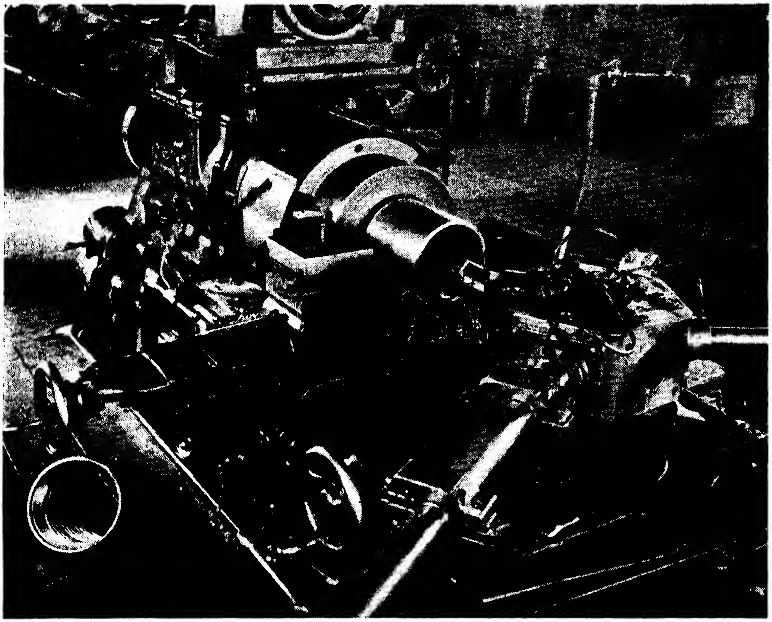


Fig. 23.—Using the cross-feeding turret slide.

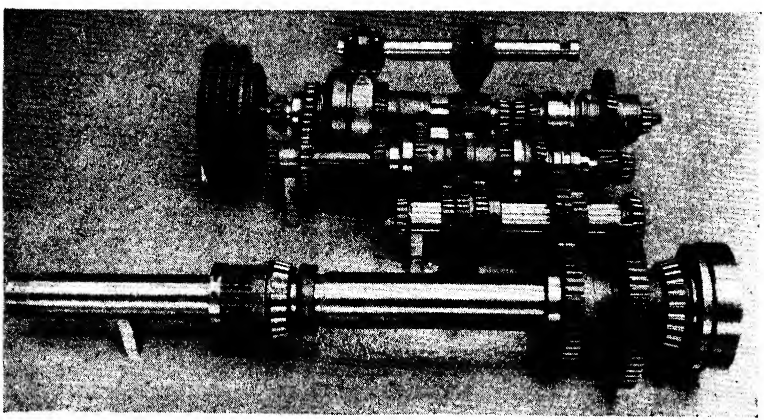


Fig. 24.—Spindle and head gearing.

turns the turret, the centering cone, the large index pins, and the clamping band are all shown.

Many special tools and fixtures are available for this, as with all modern turret lathes, these having been largely standardized but still applicable to a large variety of work. Among them are

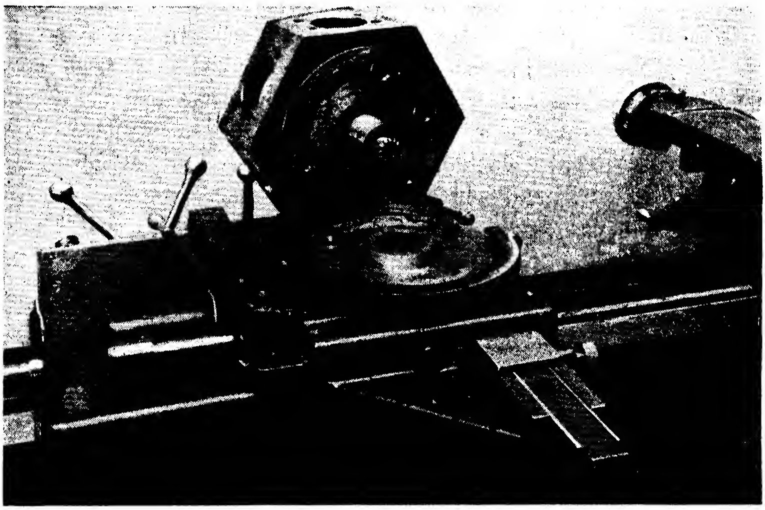


FIG. 25.—Turret indexing and clamping details.

the bar carrier (Fig. 26) which fastens directly to the headstock. This is a 2¼-in. bar and the hooks are adjustable up to 26 in. apart. This is useful in handling long and heavy work in the lathe and particularly when cutting off bars of various length.

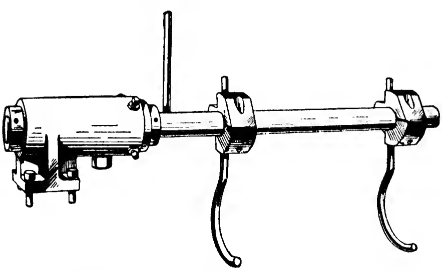


FIG. 26.—Bar carrier for heavy work.

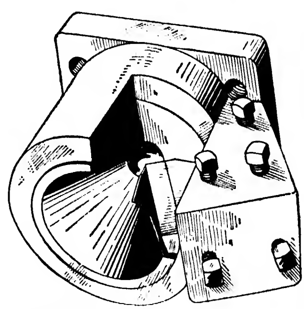


FIG. 27.—Construction of pointing tool.

The part cut off drops into the hooks instead of into the lathe bed or pan. When not needed, the hooks can be swung back out of the way. A rigid pointing tool is also on the list, as shown

in Fig. 27, as well as a great variety of roller turning tools and other tools for special work. Guides for turning taper are also available.

High-rate Metal Removal.—Removing metal at the modern rate from some of the alloys now being used imposes a severe stress on the feeding mechanism. Some idea of this stress may be had by considering a bar of high tensile strength being cut at 51 ft. per minute with a feed of 0.168 in. (over $\frac{5}{32}$) and with a cut $\frac{3}{8}$ in. deep. The feeding power is transmitted through a shear pin of drill rod which fails before the mechanism of the lathe can be damaged. This shear pin is readily accessible and can be replaced in less than 5 min.

CHAPTER X

SEMI-AUTOMATIC LATHES

THE FAY LATHE

The Fay semi-automatic lathe is a machine developed for intensive production on turned work within its range. It possesses abundant power and accuracy and is changed readily from one job to another. It is adapted to the machining of forgings, castings, or bars that may be held on centers, machining of chuck work, or work mounted on fixtures or arbors. Such work as ring forgings and gear rings up to the capacity of the machine, and short shafts or six-cylinder automotive crankshafts, and camshafts is easily handled; also the turning of spur and bevel-gear blanks, pulleys, pistons; and straight, taper boring and facing of straight and beveled surfaces. Irregular surfaces may be profiled or wide forming cuts may be taken for such surfaces. Single cuts may be taken or several cuts made simultaneously in different directions. If desired, work may be roughed in one automatic lathe and finished in another. However, on account of the rigidity of the design, a great deal of work may be finished to size in one cut in one operation.

General Cycle.—All feeds and combinations of feeds are completely automatic, the tools returning to starting position and the machine stopping automatically when the cut is completed. When the machine is in operation, the operator has only to load the machine and pull down the starting lever.

The starting lever seen at the front of the head in Fig. 28, engages the main-drive clutch in the drive pulley, thus causing the spindle to revolve. As soon as the spindle starts, a fast-motion pulley at the back of the machine also revolves and drives the fast-motion clutch. The pump immediately floods the work with cutting compound. The cam drum, at the left end of the machine, starts rotating in fast motion, being driven by the fast-motion clutch pulley referred to. This fast motion of the cam drum brings the tools immediately up to the work ready to

start the cut. A dog mounted on the cam drum in the proper position then strikes the fast-motion lever, thus automatically disengaging the fast-motion clutch in the fast-motion pulley and throwing the cam drum into slow motion just as the tools start to cut.

The cam drum is driven by a worm on the feed shaft which engages with the worm wheel shown at the right-hand end of the drum. When the fast-motion clutch is disengaged, a

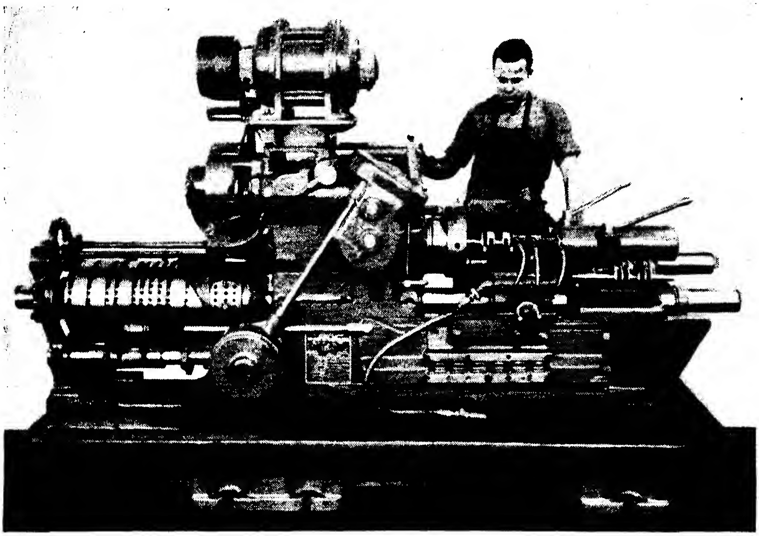


FIG. 28.—The Fay semi-automatic lathe.

ratchet gear in the bevel-gear housing shown at the front of the feed shaft drives the feed shaft in slow motion at the proper rate for feeding the tools through their cuts. The slow motion of the feed shaft is derived from the feed rod shown in obliquely placed bearings at the front, the velocity of this rod (and rate of feed carried) being determined by the change gears mounted on their respective studs in the change-gear housing at the top of the front face of the headstock.

Rapid Return.—As soon as the tools reach the end of their cuts, another dog on the cam drum throws the fast-motion lever in the opposite direction, thereby engaging the fast-motion clutch on the back end of the feed shaft, and automatically throwing the cam drum into fast motion. One of the relieving

cams on the cam drum then automatically relieves the tools in the carriage on the center bar, after which both the back arm and carriage are returned in fast motion to their starting positions and backed well away from the work, to allow the operator sufficient room to change pieces.

At this instant the machine stop dog on the end of the cam-drum worm gear automatically trips the stop lever which in turn allows the starting lever to spring up into position thus disengaging the main-drive clutch and applying the brake to the

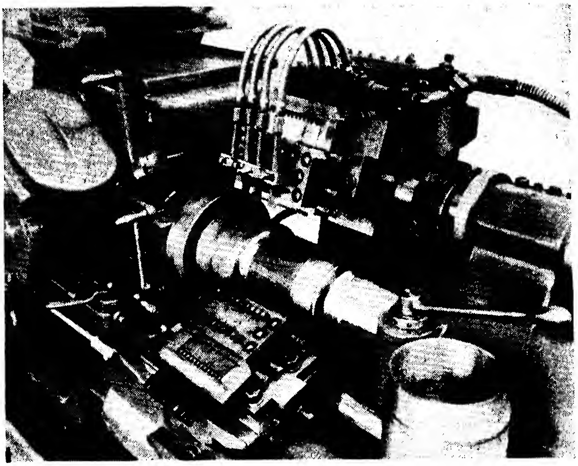


FIG. 29.—Front and back tool carriers.

fast-motion pulley at the back of the machine, instantly stopping the machine. The operator then removes the finished piece of work, places another piece in the machine, pulls the starting lever, and the machine again goes through its cycle.

The back arm is shown in Figs. 28 and 29. It is a rigid, solid casting which is clamped to a large, accurately ground steel bar extending the entire length of the machine and carried by adjustable bearings in both the headstock and tailstock. The lower end of the back arm (Fig. 30) carries an adjustable slide on which is mounted a hardened pivoted shoe. This bears on a former bar, the latter being attached to the back-former slide, which in turn is moved longitudinally by cams on the outside of the cam drum. By placing the stop collar and back-bar roll carrier on the back bar on either side of the rear bearing for the back

FIG. 30.—Details of back-former slide.

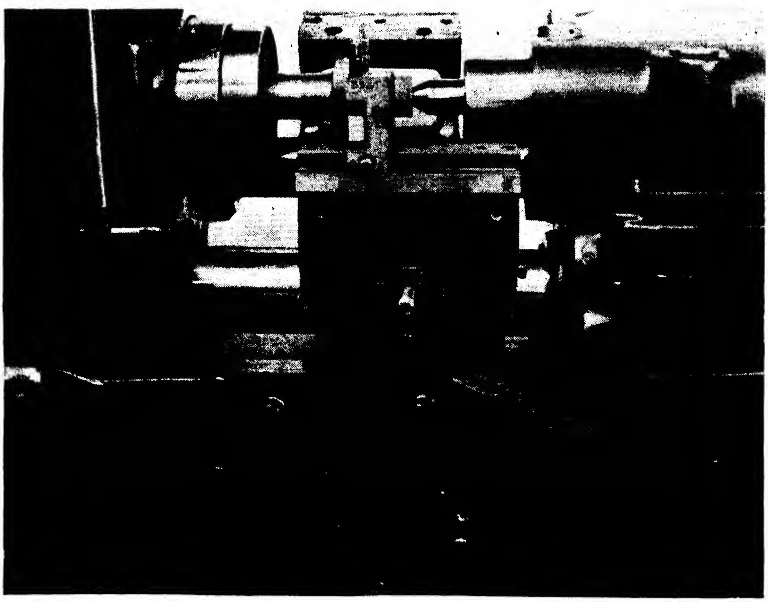


FIG. 31.—Front-former slide.

bar, and by pulling the back former under the back arm, the back arm is rocked forward for taking facing cuts. If desired, however, the back bar may be moved longitudinally, with the former slide stationary, so as to use the back arm for straight or taper turning, or for profiling when a back former of the required shape is used. By using the bevel attachment, the back arm may be used for facing bevel surfaces.

The front-former slide is shown in Figs. 28 and 31, the latter showing it set so that the carriage shoe rests on the high point of the front former. The shoe and former are clearly seen at

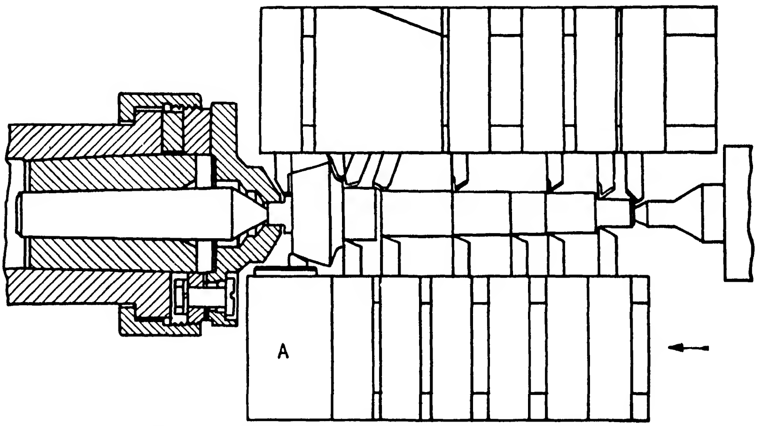


FIG. 32.—Tools for roughing a bevel stem pinion.

the front of the detail in Fig. 31. Control of any outline of cut is obtained accurately by this means.

Typical Set-ups.—The diversity of work handled on this machine makes adequate examples of all lines impossible. A few typical views are included here to show, as in Figs. 32 and 33, the tooling for roughing and finishing a bevel stem pinion. The piece is forged with a flat tang on one end which is used to engage a floating driver on the faceplate. All the turning is then done in the Fay automatic lathe, the roughing being done on one machine and the finishing on the second.

Figure 34 shows the tool layout for turning countershaft gears which are finished from forgings with holes finished, keyway broached and one end of the hub faced before coming to the automatic machine. The gears are then roughed all over in one

automatic and finished in the second, both machines being tooled alike.

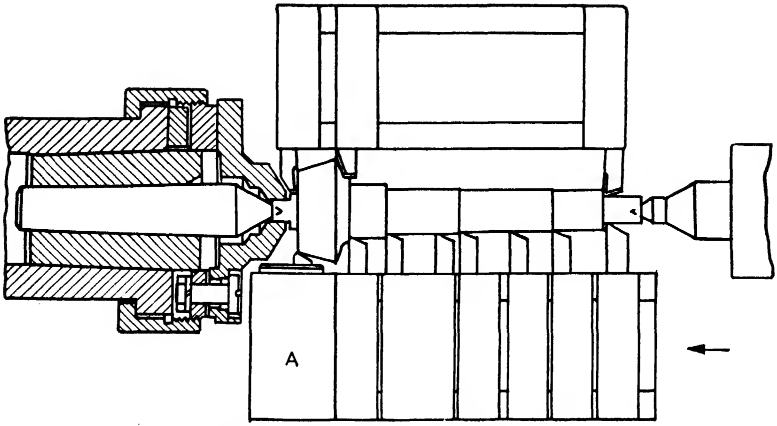


FIG. 33.—Finishing tools for same job.

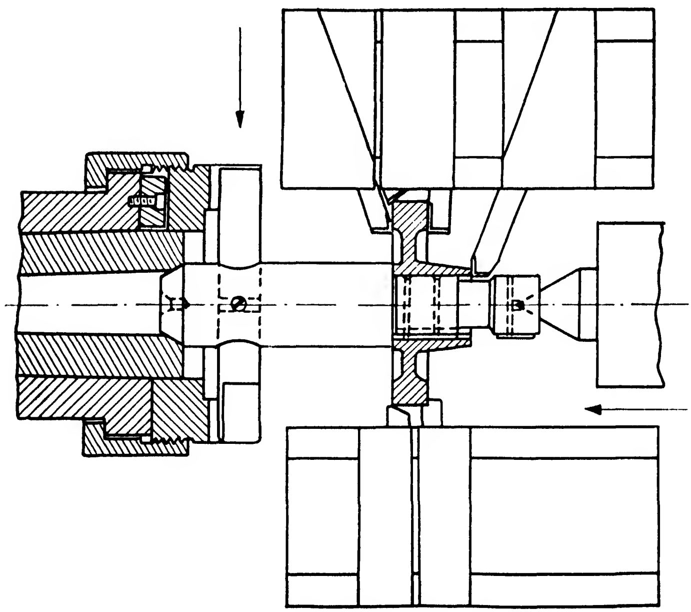


FIG. 34.—Tool layout for countershaft gears.

Work of various kinds is just as readily handled in the chuck or on special arbors of faceplate fixtures. The carriage move-

ments on the center bar (through the cam action) and the back-arm movements, with the cam and former-bar control of all movements of tools, enable all kinds of shapes to be produced with accuracy and economy of time. These Fay automatic lathes are built in various sizes by the Jones and Lamson Machine Company.

GISHOLT SIMPLIMATIC LATHE

Another Gisholt lathe of unique design is the Simplimatic, which comes in the semi-automatic class. The headstock con-

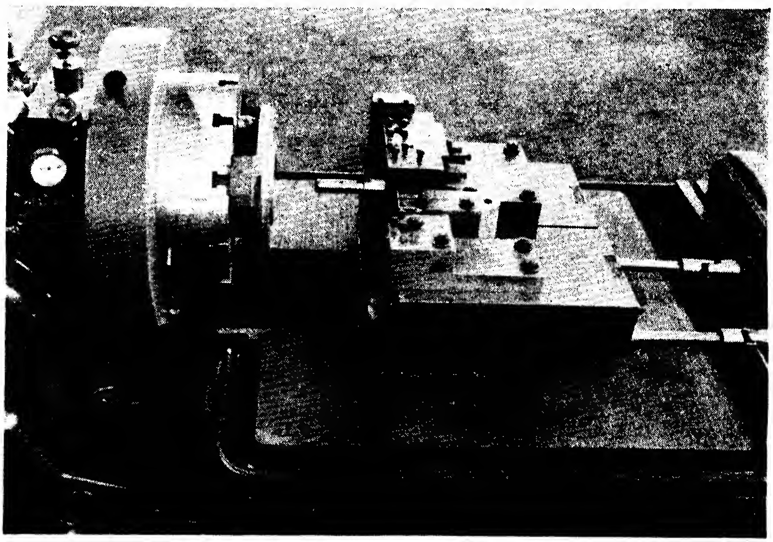


FIG. 35.—Flywheel set-up on Gisholt Simplimatic.

struction is somewhat similar to that of the turret lathe, but here the similarity ends. Instead of the cross slide and turret, there is a large rectangular table with lengthwise feeding mechanism. On this table can be mounted about any sort of tool-holding and operating device that ingenuity can produce. This tooling is very simple on some jobs and rather complicated on others, as will be seen. But the combinations that are not only possible but practicable are extremely interesting to any turret-lathe man.

Two Motor Flywheel Set-ups.—In Fig. 35 for example is the third and last operation on a motor flywheel. Three lathes

in a group handle the job, one after the other. All tools are bolted to the surface of the flat table and can move forward with it, or any of the tools can be advanced independently. The independent movement is secured from gearing at the end of the lathe and transmitted through shafts and universal joints.

An entirely different set-up, which illustrates the flexibility of the machine, is seen in Fig. 36, where an automobile-engine flywheel is being turned and bored. The work is held in a very rigid chuck. The front tool slide roughs and finish turns the out-

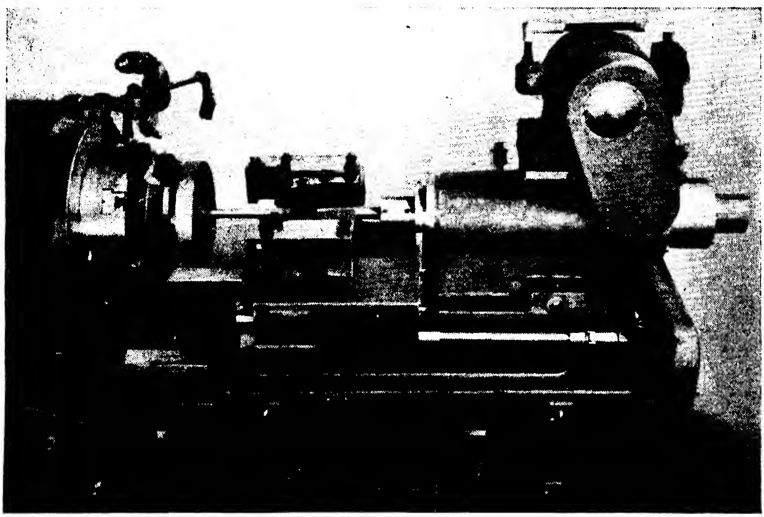


FIG. 36.—A very different set-up on same machine.

side of the flywheel and chamfers the hub. The tools in the rear tool-block straddle face the rim and also face the end of the hub. At the same time the hole is bored by the independently driven boring bar as shown. This boring bar has its own motor and can run at the proper boring speed which is, of course, faster than that for turning the rim.

Figure 36 also shows how the different tool slides are moved independently of the carriage itself, by shafts with universal joints. They can be moved in either direction, lengthwise with the table or across it as in the case of the rear tools that straddle face the rim of the wheel.

Section III

AUTOMATIC SCREW MACHINES

CHAPTER XI

AUTOMATIC SCREW-MACHINE WORK

The production of work in the screw machine, either hand or automatic, is usually a matter of handling bar stock—round, hexagon, or square—of steel, brass, aluminum, or other material. Sometimes the machine is fitted up for machining castings and forgings. Chucking work is commonly done in the larger types of machines known as turret lathes. In some designs these lathes handle large pieces, either by semi-automatic or by fully automatic action after the piece has been secured in the chuck. Some of these machines work also from large-bar stock, ranging up to several inches in diameter. In all cases, the principle of design is the use of a chucking or work-holding means, with a slide for carrying a turret and a carriage or cross slide on the bed for mounting either a second turret or some other form of cross-slide tool holder. The turret and other tool-holding devices are adapted for mounting a wide variety of tools which are applied to the work either singly or in groups according to the character of the piece and the cuts which are required to be taken.

In this way drilling and other internal operations may be carried on while external forming or cutting-off tools are at work. Drilling and turning may proceed with tools in a single holder working from the main turret, leaving other turret holes free for succeeding cuts and both ends of the cross slide available for forming, knurling, etc., and finally cutting off. Tapping, external threading, cross drilling, slotting (as for screw heads), and other operations may all be performed by the full automatic process, if the work is within the range of capacity of the automatic machine.

In the automatic screw-machine class there are two distinct types, the single-spindle and the multiple-spindle machines. The latter has a series of spindles each carrying a bar of stock which is presented in turn to the successive tools so that the different bars are under operation at the same time.

Estimating Costs.—Estimating on screw-machine work involves allowance for considerable waste of the bar material. The average width of cut-off tool is $\frac{1}{8}$ in. For the larger work it will range up to $\frac{3}{16}$ in., while for small parts it may be only $\frac{3}{32}$ in. thick. Usually $\frac{1}{8}$ in. is close to the conventional width. This then means that for every piece finished and cut from the bar there is a waste of $\frac{1}{8}$ in. which in the average length of work of say $1\frac{1}{2}$ to 2 in. will amount to 6 to 8 per cent of the stock length actually consumed in making the pieces. To this must be added for each bar about 3 in. or more for the end of the bar unused because it provides the gripping portion for holding the entire bar in the collet during its operation. A 3-in. length on a 10-ft. bar amounts to exactly 2.5 per cent of the bar. Thus we have a total wastage of 6 to 10 per cent or more to be allowed for in making up an estimate of the footage of bar material required for certain thousands of pieces of given length. Where short work is being made as, for example, special nuts or short collars or other thin parts, the cut-off waste is very heavy based upon percentages of work length. Take a piece of work which is to finish, say, $\frac{1}{2}$ in. long and where at least $\frac{1}{8}$ in. will be wasted by the cutting-off process. This means 20 per cent waste to start with. In fact in some cases it exceeds this percentage. Consequently the estimator must look into this waste in making up his costs for a run of work.

One thing that the average consumer does not appreciate in connection with screw-machine-work estimates is that on much of this work, as is also the case with most lathe work turned from steel stock, there is a considerable percentage of metal turned down into chips; this in addition to the amount mentioned as cutaway in severing the piece from the bar. Consider a $\frac{1}{2}$-in. standard cap screw 2 in. long machined from $\frac{3}{4}$-in. hexagon steel, the size of the finished head. In turning down the screw body and threading, almost one half of the material is cut into chips and, with the allowance for cutting off, more than half of the metal takes the form of chips. For this reason it cannot be assumed from the weight of 100 finished screws that this is the weight of stock necessary to make the lot.

Naturally this turning down of the metal is inherent in all machining from the bar, but the economies of screw-machine operation are such that any waste in material is more than

compensated for by the rapidity and uniformity of results secured. While the larger classes of machines known as turret lathes and turret machines handle large-bar stock, they are also well adapted to machining forgings and castings through the aid of chucking facilities and adequate turret and cross-slide tools.

Hand and Automatic Machines.—While small lots of work are usually run off on hand and semi-automatic machines, there is always a chance for the specialty shop to keep one or more automatic screw machines available for short runs by minimum cam changes, assuming one is willing to use a little more time in producing the lot of work in preference to taking more time in special set-ups. Chucks and collets will, of course, require changing to suit the size of material to be run. But certain conventional cam changes or adjustments can be made without timing to the closest figure possible or desirable, where volume production is required.

The same rule applies to box tools and other cutting tools used in the turret. Where long runs are to be made, combinations of tools in one holder and special forming tools are essential for rapid production. But for short jobs the use of an extra box tool or turning tool requiring one more cutting stroke of the turret is not necessarily detrimental and the same is true of back and front cross-slide tools. Sometimes a pair of cutting tools can be ground to produce a certain form in combination, side by side in a plain holder, where otherwise an expensive forming tool would be required. Also such a form can sometimes be produced on the work by shaping one of the box-tool cutters or other turret tool and thus avoid a special forming tool.

Moreover, after a shop has been in business for some years, there has accumulated a large variety of special tools as well as standard equipment, and out of this store of tools selections are possible for many short jobs that turn up. This applies to forming tools as well as to turning appliances commonly used in the turret. Many parts to be made require some artistic contour or perhaps a straight-shouldered effect which is not particular as to exact proportions, and in such instances an approximate form is suitable and may perhaps be available in the supply of tools already on hand.

Drills, dies, taps, and their holders are as readily adaptable to automatic turrets as to hand machines. Skill in adjusting

automatic apparatus makes it possible to utilize such machines for many parts usually turned out on hand machines because of the limited number wanted in one order. This applies especially to the smaller sizes of automatic screw machines which are compared as to capacity with small hand screw machines rather than with the regular engine lathe which comes more into competition with the larger sizes of turret lathes, of both hand and automatic types.

Competition of Processes.—The screw machine in its original hand form and in its development into automatic design was built for manufacture of small screws, pins, and studs, particularly the fastening elements that entered into sewing-machine and firearm construction. This was all small work and the volume was also small compared with modern production. The quality of the product and the rate of output encouraged the building of larger machines, and a very much wider field was opened for the use of automatic and hand machines.

With this expanding opportunity came competitive processes, some of them reducing the amount of material required for a certain class of work, others revolutionizing production rates, and still others (utilizing abrasive materials) permitting of finer degree of accuracy, as in the case of steel-ball manufacture.

Thus, swaging, press stamping, cold and hot forging and upsetting, and more recently die casting have each taken over at one time or another certain lines of work that were originally within the special province of the screw machine. But newer articles came along to replace lost business in such details, and increased capacity as to size of work and flexibility of operation have provided the screw machine and the turret lathe with a field in manufacture which early designers could never have considered as even a bare possibility.

It must be remembered, however, that even with these other processes, the screw-machine application often has a marked advantage in simple tool expense and lost cost of operation, especially for limited and medium runs of work within its field. This fact frequently offsets the saving of a stamping where an expensive set of press tools is not warranted unless a large number of parts are required.

In many cases, too, other processes necessitate a second operation for finishing the piece, either in a screw machine or

other cutting equipment. Bolts upset from small bars with no waste of material have to be threaded and probably faced at least under the head. Nuts require tapping and facing. Some work comes to the hand screw machine for finishing operations. Other work is fed from magazines into the chuck of the full automatic machine. As a rule, however, bolt blanks and studs are threaded in bolt-threading machinery.

Screw-machine Flexibility.—The automatic screw machine permits a liberal choice between finishing a part completely in the collet or leaving some one or more operations for another machine. There are some classes of parts that cannot be completed on the end nearest the collet until the part has been cut from the bar of stock. Then, by transfer devices, they can be brought into position for a second operation, such as the sawing of the slot into a screw head or the threading of the inner end of a stud already finished on the outer end thread.

It is sometimes a question as to how far to proceed with a given piece of work such as finishing it completely in one run. It depends largely upon the quantity of pieces to be made and hence the amount of setting up feasible for the work. Great ingenuity has been displayed in the design of special attachments for cross drilling, slotting, and other operations.

An interesting example consists of a "set-up" for completing a special nut requiring chamfering on front and back faces and at the front and rear ends of the tapped hole. The chamfering of the corners of outer and back face of the nut is accomplished by a forming tool of the usual type. The inner chamfering or beveling out of the thread at front and back requires a forming tool like a small spool which is carried in a small cross slide in the turret and fed into fixed position by the action of the regular cross slide of the machine. The nut, when cut off, comes out smooth and parallel with both ends of the thread nicely chamfered out.

Second-operation Selection.—The question arises in many instances as to whether it is desirable to complete work similar to this nut in the one set-up, if on a single-spindle machine, or whether it should be handled in two operations. In this case the internal cut with the slender forming tool is not a rapid one and the facing and chamfering out of the rear end of the nut could probably be done more economically with a simple second opera-

tion involving only running the nut on to a thread arbor in a light lathe spindle and facing and chamfering exactly true with the tapped hole. Or some regular attachment may be used on the automatic screw machine.

Each job is to be considered by itself, when the matter of second operations is up for examination. As pointed out previously, the quantity of pieces ordered is usually the first thing to be considered. In any event, the hand screw machine offers a simple solution of a variety of second-operation problems as the facilities for chucking and finishing are ideal for the majority of parts coming within the range of capacity necessary for the work in hand.

Simple examples are such parts as the studs already mentioned, where a second end requires threading, and possibly some other finishing cut; various parts requiring special burring; knobs and handles which require recesses in the head end for reception of screw or detent pin.

Some second operations, such as assembling of certain pieces, require swaging or staking operations under the punch press; for light work this is usually a foot press. An example is a small gear blank or disk which is formed in the automatic screw machine for use in light mechanism similar to clockwork. The blank is produced from the bar with a short hub drilled and machined to diameter ready for insertion in a hole punched or drilled in the part to which the gear blank is to be attached. The operation of fixing the hub in place is carried out with simple staking tools which swell the hollow end of the hub tightly in its seat in the adjacent part.

Special Stock Sections and Materials.—The fact is sometimes overlooked that round, square, and hexagonal stocks are not the only sections available for working in the automatic screw machine. Various other shapes are drawn, especially in the smaller sizes. Among them is "pinion wire," which is a convenience to makers of different kinds of geared mechanism where the expense of cutting small pinion teeth is avoided. The simple process of cutting off the specified wire to the desired width of face is all that is necessary.

The use of tubular stock is found convenient for some classes of work such as thin-walled bushings, spacing washers and collars, and small rollers. This material may require turning

or forming on the outside to bring it to the necessary diameter or it may have to be bored out internally to whatever size is required.

A single-point tool is as readily applied here as in the lathe if for any reason it seems to be desirable. For instance, it may be necessary to cut a recess in the interior of the bore, or a simple truing cut may be desired for some special job without application of a reamer. A boring tool of this character in a special turret holder which admits of cross movement allows the cross slide to control the cutting action of the tool as it is fed through the work by the advance of the turret slide.

CHAPTER XII

SETTING UP AND OPERATING AUTOMATIC SCREW MACHINES

In the following pages a few general suggestions are given which may be of interest to operators before considering in detail the different types of tools, determination of speeds, feeds, etc., treated fully in Chaps. XVI and XX.

It should be borne in mind that the automatic screw machine necessarily has more complicated mechanism than a hand-operated machine, as many movements must be performed automatically which in the hand type of machines are accomplished by the operator. The automatic machines must, therefore, have the more careful attention in setting up for turning out work. When, however, the machines are properly adjusted, little more attention than that required on a hand machine is needed, although the use of dull tools must be particularly guarded against.

Ordinarily a workman will readily attend to several machines. He should become thoroughly familiar with the machine operations and adjustments before putting in tools or starting up, and it is generally well first to operate the machine by hand before putting on power.

If a new piece of work is to be produced on an automatic screw machine, it is well to consider first the various ways in which the work may be machined, the tool equipment available, and the quantity of pieces to be made, and then to decide upon a satisfactory method.

Tools and Collets.—The preparation of special tools and the changing of the camming of the machine (if any) must then be attended to. All tools and holders must be made accurately to give correct results, and in addition it is always advisable to check the first few pieces produced, by gages or otherwise, to see that the pieces are of the correct dimensions. The collet should grasp the rod the entire length of the bearing surface, and

have a tendency to bite harder on the front end than at the rear. This affords rigidity to the work when a cross-forming operation is being performed. The front end of the collet should likewise have a good bearing in its seat. The collet when closed must firmly grip the rod so as to prevent any slipping under the action of the cutting tools.

Handling Material.—The feeding chuck must have sufficient grip to feed the rod accurately without undue marring of the material upon its return stroke. It is generally considered well to straighten the bars of stock if they are bent, and also to gage them for diameter and to stack them into separate bundles if there is an appreciable variation which would cause difficulty when machining, and afterward to make adjustment of the collets, etc., to suit the various sizes as worked up.

Where different qualities of steel are being used, extreme care must be taken to prevent mixing in a hard-tool-steel bar with the soft-steel stock from which the work is supposed to be made, as the speed of the spindle and the feed may be such as to ruin expensive tools.

Tool and Other Adjustments.—It is, of course, obvious that the lubricating system should be known to be properly working and all cutting tools should be properly set with regard to the work and their cutting edges properly ground in order to get good results.

The head-spindle bearings must be adjusted so as to permit running of the spindle at satisfactory speed without unreasonable freedom. The cross slide, turret, and turret-slide bearings must also be kept in good condition.

The selection of the proper spindle speeds for various jobs, as well as the determining of satisfactory feeds, should be considered carefully: Tables I to VIII should be helpful in this connection.

Production.—The rate of production is dependent not only on the rate of feed and spindle speed but also on the tool equipment. The production of threaded work especially is facilitated by employing tools so designed as to take advantage of two speeds and to cut when the spindle is reversed.

The camming should permit the performing of several operations simultaneously, such as drilling from the turret and forming from the cross slide.

Manipulation of Tools.—When changing the tool equipment from one piece to another the seat in the head spindle for the collet as well as the collet must be thoroughly cleaned, so as to avoid eccentricity in the operation of the rod due to foreign matter, when the stock is grasped by the collet.

Before dismantling tools it is well to make a model on the automatic screw machine for convenience in setting up in the future. This model should be complete in all respects but should not be fully cut off to its usual length. It should be left intact, with sufficient length of the bar to permit grasping by the collet, allowing the model to be the proper working distance from the

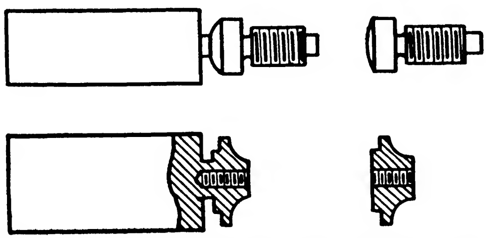


FIG. 1.—Setting up models for screw-machine work.

end of the spindle. Figure 1 shows two models with the piece of stock by which they are held when setting up for the production of similar work.

Speeds and Feeds for Screw-machine Work.—The following tables on speeds and feeds are devoted more especially to the smaller and medium sizes of work as ordinarily produced on the automatic screw machine. In many instances much larger work is handled on such machines, and turret lathes especially are required to do much work where large or fairly large sizes of tools are necessary. Consequently the tables in the present chapter should be of value in determining approximations to the requisite speeds and feeds for jobs ranging up to reasonably large diameters. These tables also include computed numbers of revolutions of work to correspond to recommended surface speeds as expressed in feet per minute.

The ordinary class of screw-machine tools, suitable speeds and feeds for which have to be determined when camming automatics, includes the various turning tools such as box tools (adjustable and nonadjustable), hollow mills, drills, reamers, counterbores, taps and dies, forming and cutting-off tools. The accompanying

tables of speed and feeds for different types of tools used on materials commonly worked in the automatic have been compiled from data accumulated and thoroughly tested during extended experience in this class of work. They have proved of value in the screw-machine department not only in connection with the handling of automatics but also, to a considerable extent, on hand machines. Naturally, the matter of feeds on the latter class of apparatus is largely regulated by the personal equation; the question of spindle speeds, however, is quite as important and as readily settled for hand machines as for automatics.

It is, of course, impossible, where a series of tools is used on an automatic machine to select speeds theoretically correct for each and every tool carried by the turret and cross slide. A compromise is necessary and therefore speeds are selected which will fall within the range suitable for the different tools; in determining these surface speeds and the rates at which to drive the spindle to approximate closely the desired surface velocities, the tables should be found of service.

Speeds and Feeds for Turning.—Tables I and II cover turning speeds and feeds for bright-drawn stock (screw stock) and brass, with various depths of chip (that is, stock removed on a side) from 1/32 in. up to 3/8 in. These speeds and feeds and depths of cut are figured more especially for such tools as roughing boxes where the cut, though frequently heavy, is taken by a single cutting edge, the work being well supported behind the cutter during the operation. Table III covers the same range of steel work as Table I but is laid out for hollow-mill operations; it will be noticed that, the cut being divided with this tool among three or more cutting edges, coarser rates of feed are provided for than with the box tool. With both classes of tools the feeds are, of course, increased as the diameter of the stock increases, the peripheral speeds being reduced as the feeds grow coarser and the chip greater in depth.

The speeds and feeds for finishing box tools as used on different materials are given in Table IV, the last column indicating the amount of stock which, generally speaking, it is advisable to remove in order to produce a good surface.

Forming-tool Speeds and Feeds.—Speeds and feeds for forming tools are given in Table V, the widths covered here ranging from 1/16 to 2 in., and the smallest diameter of form from 1½

down to 1/16 in. It will be seen that the tool about 1/4 in. wide is adapted to take the coarsest feed, tools from this width up to 3/16 (such as are commonly employed for cutting-off purposes)

TABLE I.—CUTTING SPEEDS AND FEEDS FOR SCREW-MACHINE WORK: SCREW STOCK

1/32-in. chip				1/16-in. chip				1/8-in. chip			
Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.	Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.	Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.
1/8	80	2,445	0.002	1/4	60	916	0.0035	3/8	55	560	0.004
3/16	70	1,426	0.003	3/8	60	611	0.004	1/2	55	420	0.005
1/4	70	1,069	0.004	1/2	60	458	0.005	3/4	55	280	0.006
3/8	70	713	0.005	3/4	55	280	0.006	1	50	191	0.007
1/2	60	458	0.006	1	55	210	0.007	1 1/4	50	152	0.007
3/4	60	305	0.007	1 1/4	55	168	0.007	1 1/2	45	114	0.007
1	60	229	0.008	1 1/2	50	127	0.008	1 3/4	45	98	0.007
1 1/4	60	183	0.008	1 3/4	50	109	0.008	2	40	76	0.008
1 1/2	50	127	0.009	2	45	86	0.009	2 1/4	40	68	0.008
1 3/4	50	109	0.010	2 1/4	45	76	0.009	2 1/2	40	61	0.008
2	50	95	0.010	2 1/2	45	68	0.009	3	40	51	0.008
2 1/4	50	85	0.010	3	45	57	0.009	3 1/2	40	44	0.008

3/16-in. chip				1/4-in. chip				3/8-in. chip			
Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.	Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.	Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.
1/2	50	382	0.004	3/4	50	254	0.004	1 1/4	45	137	0.005
3/4	50	254	0.005	1	50	191	0.005	1 1/2	45	114	0.005
1	50	191	0.005	1 1/4	45	137	0.005	1 3/4	45	98	0.005
1 1/4	45	137	0.006	1 1/2	45	114	0.006	2	40	76	0.006
1 1/2	45	114	0.006	1 3/4	45	98	0.006	2 1/4	40	68	0.006
1 3/4	45	98	0.006	2	40	76	0.006	2 1/2	40	61	0.007
2	40	76	0.007	2 1/4	40	68	0.007	3	40	51	0.007
2 1/4	40	68	0.007	2 1/2	40	61	0.007	3 1/2	40	44	0.007
2 1/2	40	61	0.007	3	40	51	0.007	4	40	38	0.008
3	40	51	0.007	3 1/2	40	44	0.007	4 1/2	40	34	0.008

admitting of heavier crowding, as a rule, than either the narrower or wider tools. Thus we see the rate of feed drop off as a tool narrows to 1/16 in., which obviously is too thin a cutting device to

admit of taking much of a chip, while similarly as the width of form and chip increases above about 3/16 or 1/4 in. the rate of feed must again be diminished to give the best results. Naturally,

TABLE II.—CUTTING SPEEDS AND FEEDS FOR SCREW-MACHINE WORK: BRASS

1/32-in. chip				1/16-in. chip				1/8-in. chip			
Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.	Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.	Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.
1/8	180	5,500	0.003	1/4	180	2,748	0.004	3/8	165	1,680	0.004
3/16	180	3,668	0.004	3/8	180	1,833	0.005	1/2	165	1,260	0.006
1/4	180	2,748	0.005	1/2	180	1,374	0.0065	3/4	165	840	0.007
3/8	180	1,833	0.006	3/4	165	840	0.0075	1	150	573	0.008
1/2	180	1,374	0.008	1	165	630	0.0085	1 1/4	150	456	0.009
3/4	180	915	0.010	1 1/4	165	504	0.010	1 1/2	135	342	0.010
1	180	687	0.011	1 1/2	150	381	0.012	1 3/4	135	294	0.010
1 1/4	180	549	0.012	1 3/4	150	327	0.012	2	120	228	0.011
1 1/2	150	254	0.014	2	135	258	0.014	2 1/4	120	204	0.011
1 3/4	150	218	0.014	2 1/4	135	228	0.014	2 1/2	120	183	0.012
2	150	190	0.015	2 1/2	135	204	0.014	3	120	153	0.012
2 1/4	150	170	0.015	3	135	171	0.014	3 1/2			
3/16-in. chip				**1/4-in. chip**				**3/8-in. chip**			
Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.	Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.	Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.
1/2	150	1,146	0.005	3/4	150	762	0.005	1 1/4	135	411	0.007
3/4	150	762	0.006	1	150	573	0.006	1 1/2	135	342	0.008
1	150	573	0.007	1 1/4	135	411	0.007	1 3/4	135	294	0.008
1 1/4	135	411	0.008	1 1/2	135	342	0.008	2	120	228	0.009
1 1/2	135	342	0.009	1 3/4	135	294	0.008	2 1/4	120	204	0.009
1 3/4	135	294	0.009	2	120	228	0.009	2 1/2	120	183	0.010
2	120	228	0.010	2 1/4	120	204	0.009	3	120	153	0.010
2 1/4	120	204	0.010	2 1/2	120	183	0.010	3 1/2	120	131	0.010
2 1/2	120	183	0.010	3	120	153	0.010	4	120	114	0.010
3	120	153	0.010	3 1/2	120	131	0.010	4 1/2	120	102	0.010

other things being equal, the greater the diameter of the section formed the coarser the feed which can be taken economically. This is also indicated by the figures in tables given.

Drilling and Reaming Data.—Drilling speeds and feeds are given in Table VI. While these speeds are based on much higher peripheral velocities than drillmakers as a rule recommend for

TABLE III.—CUTTING SPEEDS AND FEEDS FOR SCREW-MACHINE WORK: HOLLOW MILLS; SCREW STOCK

1/32-in. chip				1/16-in. chip				1/8-in. chip			
Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.	Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.	Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.
1/8	80	2,445	0.0026	1/4	60	916	0.0045	3/8	55	560	0.0052
3/16	70	1,426	0.0039	3/8	60	611	0.0052	1/2	55	420	0.0065
1/4	70	1,069	0.0052	1/2	60	458	0.0065	3/4	55	280	0.0078
3/8	70	713	0.0065	3/4	55	280	0.0078	1	50	191	0.0091
1/2	60	458	0.0078	1	55	210	0.0091	1 1/4	50	152	0.0091
3/4	60	305	0.0091	1 1/4	55	168	0.0091	1 1/2	45	114	0.0091
1	60	229	0.0104	1 1/2	50	127	0.0104	1 3/4	45	98	0.0091
1 1/4	60	183	0.0104	1 3/4	50	109	0.0104	2	40	76	0.0104
1 1/2	50	127	0.0117	2	45	86	0.0117	2 1/4	40	68	0.0104
1 3/4	50	109	0.013	2 1/4	45	76	0.0117	2 1/2	40	61	0.0104
2	50	95	0.013	2 1/2	45	68	0.0117	3	40	51	0.0104
2 1/4	50	85	0.013	3	45	57	0.0117	3 1/2			

3/16-in. chip				1/4-in. chip				3/8-in. chip			
Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.	Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.	Dia. of stock	Feet surface speed	Rev. per min.	Feed per rev.
1/2	55	420	0.0052	3/4	50	254	0.0052	1 1/4	45	137	0.0065
3/4	55	280	0.0065	1	50	191	0.0065	1 1/2	45	114	0.0065
1	55	210	0.0065	1 1/4	45	137	0.0065	1 3/4	45	98	0.0065
1 1/4	50	152	0.0078	1 1/2	45	114	0.0078	2	40	76	0.0078
1 1/2	50	127	0.0078	1 3/4	45	98	0.0078	2 1/4	40	68	0.0078
1 3/4	50	109	0.0078	2	40	76	0.0078	2 1/2	40	61	0.0078
2	40	76	0.0091	2 1/4	40	68	0.0091	3	40	51	0.0078
2 1/4	40	68	0.0091	2 1/2	40	61	0.0091				
2 1/2	40	61	0.0091	3	40	51	0.0091				
3	40	51	0.0091								

general purposes, it should be remembered that conditions for drilling in the automatic on the usual run of work are nearly ideal so far as lubrication of drill and work, steadiness of feed,

etc., are concerned, and it is possible under these conditions where the holes drilled as a rule are comparatively shallow and the drill has ample opportunity for cooling during the operations carried on by the other tools, to maintain speeds that would be considered too high to be attempted in general shop practice.

Table VII is made up of speed and feed data for reamers. In this table the feed for different classes of material has been considered as constant for any given diameter of reamer, although it is conceivable that with certain materials, especially on brass alloys, the feed per revolution might be increased somewhat, to

TABLE IV.—CUTTING SPEEDS AND FEEDS FOR SCREW-MACHINE WORK: FINISH BOX TOOL

Finished diameter of work	Screw stock			Brass rod			Cast iron			Tool steel			Amount advisable to remove on a side
	Feet surface speed	Rev. per min.	Feed per rev.	Feet surface speed	Rev. per min.	Feed per rev.	Feet surface speed	Rev. per min.	Feed per rev.	Feet surface speed	Rev. per min.	Feed per rev.	
1/16	80	4,889	0.003	180	11,000	0.003	..	.....	......	40	2,445	0.002	0.002
1/8	80	2,445	0.0045	180	5,500	0.0045	..	.....	......	40	1,222	0.003	0.0025
3/16	70	1,426	0.0055	180	3,668	0.0055	70	1,426	0.0055	40	815	0.003	0.0025
1/4	65	993	0.0075	180	2,750	0.0075	70	1,069	0.0075	35	531	0.004	0.0045
1/2	60	458	0.011	180	1,375	0.011	65	496	0.011	35	267	0.005	0.006
3/4	60	305	0.012	180	917	0.012	65	331	0.012	35	178	0.007	0.006
1	60	229	0.012	175	668	0.012	60	229	0.014	30	115	0.009	0.0065
1 1/2	55	140	0.014	170	433	0.014	60	153	0.016	30	76	0.009	0.007
2	50	95	0.014	170	325	0.014	60	115	0.016	30	57	0.009	0.008

advantage, over the rates given. These feeds have been tabulated, however, as representing highly satisfactory practice in reaming the materials listed.

Threading and Counterboring.—Table VIII explains itself and, while giving speeds for threading work with dies, should be of equal value in establishing speeds for tapping. It should be noted that the speeds in this table are proper for *high-speed* dies. For *carbon-steel* dies the speeds used should be from 50 to 75 per cent of the rates given.

For feeds for counterbores from 3/8 to 2 in. diameter, Tables I and II for turning may be followed where the counterbores cut to a depth from one half to three quarters their diameter. Where cutting deeper than about one diameter, the feeds would be

decreased; in such depths it is well to withdraw the counterbore during the cutting operation to free it from chips.

It is not expected that the speeds and feeds laid down in these tables will coincide exactly with the ideas of everybody engaged

TABLE V.—SPEEDS AND FEEDS FOR SCREW-MACHINE WORK

Dia. of work	Screw stock		Brass rod		Cast iron		Tool steel	
	Feet surface speed	Rev. per min.	Feet surface speed	Rev. per min.	Feet surface speed	Rev. per min.	Feet surface speed	Rev. per min.
	Speeds for forming							
1/8	75	2,292	200	6,112				
3/16	75	1,528	200	4,074				
1/4	70	1,069	185	2,827	75	1,146	45	688
3/8	65	662	185	1,885	70	713	40	407
1/2	65	497	185	1,414	70	535	40	306
3/4	60	305	175	882	65	331	35	178
1	60	229	175	667	65	248	35	134
1 1/2	60	153	170	432	60	153	30	76
2	50	96	170	324	60	115	30	57

Feeds for forming tools

Width of form	Smallest diameter of form							
	1/16	1/8	3/16	1/4	3/8	1/2	3/4	1 1/2
1/16	0.0007	0.0008	0.001	0.0012	0.0012	0.0012	0.0012	0.0012
1/8	0.0005	0.0008	0.001	0.0012	0.0015	0.0020	0.0025	0.0025
1/4	......	0.0007	0.001	0.001	0.0015	0.0015	0.0018	0.0018
3/8	......	......	0.0009	0.001	0.001	0.0012	0.0015	0.0015
1/2	......	......	0.0008	0.0009	0.001	0.001	0.0015	0.0015
3/4	......	......	......	0.0008	0.0009	0.001	0.0011	0.0012
1	......	......	......	......	0.0008	0.0009	0.001	0.0012
1 1/2	......	......	......	......	0.0007	0.0007	0.0009	0.0011
2	......	......	......	......	......	......	0.0007	0.001

in screw-machine operations. Conditions as to materials, lubricants, clearances of cutting edges, quality of tools, etc., all have an important bearing upon the question of efficient cutting speeds and feeds. It is believed, however, that the information

TABLE VI.—SPEEDS AND FEEDS FOR SCREW-MACHINE WORK: FOR DRILLING

	Screw stock		Brass rod		Cast iron		Tool steel	
Dia. of drill	Feed per rev.	R.p.m. at 60 ft. peripheral speed	Feed per rev.	R.p.m. at 175 ft. peripheral speed	Feed per rev.	R.p.m. at 60 ft. peripheral speed	Feed per rev.	R.p.m. at 35 ft. peripheral speed
1/32	0.0006	7,333	0.0008	21,390	0.0006	7,333	0.0005	4,278
3/64	0.0008	4,889	0.0010	14,260	0.0008	4,889	0.0006	2,852
0.059	0.001	3,884	0.0013	11,329	0.001	3,884	0.0008	2,265
1/16	0.0013	3,667	0.0017	10,696	0.0013	3,667	0.0010	2,139
5/64	0.0016	3,093	0.002	8,555	0.0016	3,093	0.0012	1,658
3/32	0.0018	2,445	0.0023	7,130	0.0018	2,445	0.0014	1,430
0.105	0.002	2,186	0.0026	6,366	0.002	2,186	0.0015	1,305
1/8	0.0025	1,833	0.0033	5,348	0.0025	1,833	0.0018	1,070
0.150	0.003	1,528	0.0039	4,456	0.003	1,528	0.0022	891
5/32	0.003	1,421	0.0039	4,144	0.003	1,421	0.0022	828
3/16	0.004	1,222	0.0052	3,565	0.004	1,222	0.003	713
7/32	0.004	1,048	0.0052	3,050	0.004	1,048	0.003	611
1/4	0.0045	916	0.0058	2,674	0.0045	916	0.0033	535
9/32	0.0045	815	0.0058	2,377	0.0045	815	0.0033	475
5/16	0.0045	733	0.0058	2,139	0.0045	733	0.0033	427
3/8	0.0045	611	0.0061	1,783	0.0045	611	0.0035	356
7/16	0.005	524	0.0065	1,528	0.005	524	0.0037	305

	Screw stock		Brass rod		Cast iron		Tool steel	
Dia. of drill	Feed per rev.	R.p.m. at 55 ft. peripheral speed	Feed per rev.	R.p.m. at 165 ft. peripheral speed	Feed per rev.	R.p.m. at 55 ft. peripheral speed	Feed per rev.	R.p.m. at 33 ft. peripheral speed
1/2	0.005	420	0.0065	1,260	0.005	420	0.0037	252
9/16	0.0057	373	0.0074	1,120	0.0057	373	0.0043	224
19/32	0.0057	353	0.0074	1,067	0.0057	353	0.0043	212
5/8	0.0059	336	0.0077	1,008	0.0059	336	0.0044	202
11/16	0.006	305	0.0078	917	0.006	305	0.0045	183
3/4	0.0065	280	0.0084	840	0.0065	280	0.0049	169
13/16	0.007	258	0.0091	776	0.007	258	0.0052	155
7/8	0.0075	240	0.0097	702	0.0075	240	0.0056	144
15/16	0.008	224	0.0104	672	0.008	224	0.006	134
		50 ft.		150 ft.		50 ft.		30 ft.
1	0.0085	191	0.0110	573	0.0085	191	0.0064	115
1 1/8	0.009	169	0.0117	509	0.009	169	0.0067	102
1 1/4	0.0095	152	0.0123	458	0.0095	152	0.0071	92
1 3/8	0.010	139	0.0130	416	0.010	139	0.0075	83
1 1/2	0.011	127	0.0143	382	0.011	127	0.0082	76
1 5/8	0.012	118	0.0156	352	0.012	118	0.009	70
1 3/4	0.013	109	0.0169	327	0.013	109	0.0097	65
2	0.014	96	0.0182	294	0.014	96	0.0105	57

should be of service to many readers, representing as it does the practice commonly followed by one of the largest tool shops with

TABLE VII.—SPEEDS AND FEEDS FOR SCREW-MACHINE WORK: REAMING

Dia. of reamer	Feed per rev.	Amount to remove on dia.	Rev. per min. Screw stock at 40 ft.	Brass rod at 130 ft.	Cast iron at 45 ft.	Tool steel at 25 ft.	Dia. of reamer	Feed per rev.	Amount to remove on dia.	Rev. per min. Screw stock at 40 ft.	Brass rod at 130 ft.	Cast iron at 45 ft.	Tool steel at 25 ft.
1/8	0.005	0.0045	1,222	3,972	1,375	764	1 1/4	0.018	0.010	122	397	138	76
3/16	0.006	0.0045	815	2,648	917	509	1 1/2	0.020	0.010	102	331	115	63
1/4	0.007	0.006	611	1,986	688	382	1 3/4	0.022	0.010	87	284	98	54
3/8	0.0085	0.006	407	1,324	458	254	2	0.024	0.013	76	248	86	48
1/2	0.0105	0.008	306	993	344	191	2 1/4	0.026	0.013	68	220	76	42
5/8	0.012	0.008	245	795	275	153	2 1/2	0.028	0.013	61	199	69	38
3/4	0.014	0.008	204	662	229	127	2 3/4	0.030	0.013	56	181	63	35
1	0.016	0.010	153	497	172	95	3	0.032	0.013	51	165	57	32

TABLE VIII.—SPEEDS AND FEEDS FOR SCREW-MACHINE WORK—HIGH-SPEED DIES: STANDARD THREADS

Dia. of thread	Screw stock Feet surface speed	Screw stock Rev. per min.	Brass rod Feet surface speed	Brass rod Rev. per min.	Cast iron Feet surface speed	Cast iron Rev. per min.	Tool steel Feet surface speed	Tool steel Rev. per min.	Cast brass Feet surface speed	Cast brass Rev. per min.
1/8	40	1,222	135	4,126	40	1,222	25	764	120	3,666
1/4	40	611	125	1,909	40	611	25	382	110	1,680
3/8	35	356	120	1,222	35	356	20	204	100	1,019
1/2	35	267	120	917	35	267	20	153	100	764
3/4	35	178	115	586	30	153	20	102	100	509
1	30	115	110	420	30	115	20	76	90	344
1 1/4	30	92	100	306	25	76	15	46	90	275
1 1/2	30	76	90	229	25	64	15	38	90	229
2	25	48	85	162	20	38	15	29	90	172

carbon-steel screw-machine tools. With high-speed steel rods most speeds can be increased from 40 to 100 per cent.

CHAPTER XIII

BROWN AND SHARPE AUTOMATIC SCREW MACHINES

The general principles of an automatic screw machine are very simple. A bar of stock is held firmly in a spindle and rotated. Various tools for working on it are held in a circular turret. The turret is advanced automatically toward the end of the bar of stock so that each tool in turn does its work. The turret is automatically rotated part of a turn after each tool has finished, bringing the tools opposite to the end of the bar, one after another. Two independent tool slides, which move at right angles to the spindle, also carry tools that work automatically on the stock. The spindle rotation is reversed and the spindle speed changed automatically for different operations when desired. After a piece of work is completed and cut off, the machine advances the bar and starts making a new piece, continuing the operations over and over until the bar is used up.

In order to make clear the names and functions of the various parts of the Brown and Sharpe automatic screw machines, we begin with a brief description of this type of machine, and tell how its working parts operate.

In this description, a view of the front (Fig. 2) and the rear (Fig. 2*A*) of the No. 2 automatic screw machine will be used as references: the same reference letters are used on sectional drawings Figs. 3, 4, and 5. All the Brown and Sharpe automatic screw machines are similar in principle, although slightly different in construction.

Power is transmitted by belts from the overhead works to a pair of friction-clutch pulleys, A_2 and B_2, for driving the spindle, one belt usually crossed, the other open, so that one pulley runs forward and one backward. These pulleys run free and either one is engaged to drive the spindle by means of the automatically operated friction clutch E_2 between them, giving a spindle drive which is instantly reversible.

A third belt from the overhead works drives the pulley K_2 and the shaft G_3* on the rear of the bed at a constant rate, regardless of the spindle speed.

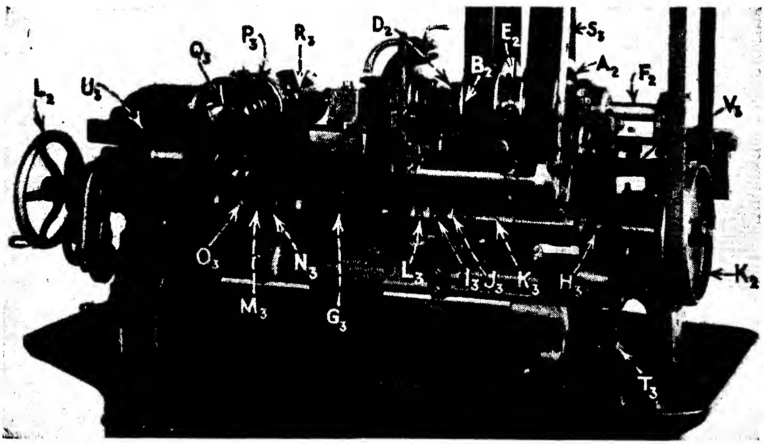


Fig. 2.—Front of No. 2 automatic screw machine. (*Brown and Sharpe.*)

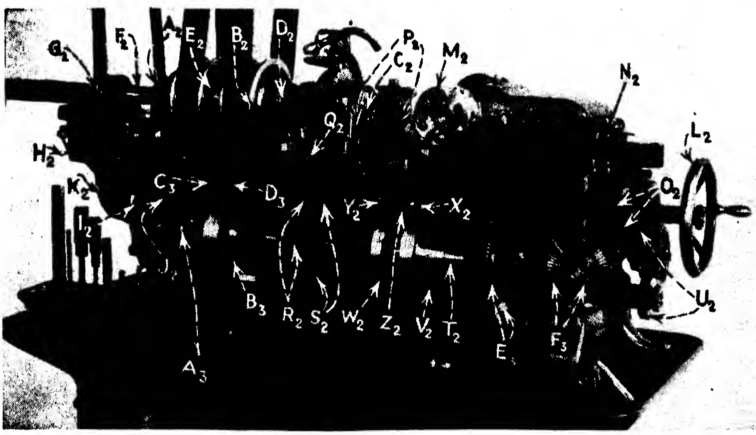


Fig. 2A.—Rear of No. 2 automatic screw machine. (*Brown and Sharpe.*)

Mounted on the driving shaft G_3 or connected with it are a number of cams, gears, and clutches for automatically performing the

* While this reference on the illustration points to the box in which the driving shaft runs, it is not possible to indicate the position of the shaft any differently as it is concealed in its bearings and by the clutches and cams for its entire length.

operations of advancing the bar of stock through the spindle for each new piece, reversing the rotation of the spindle, indexing the turret around, and automatically changing the spindle speed. That is, all movements of the machine, except driving the spindle, take their power from this shaft. Therefore the entire mechanism of the machine, except the spindle, can be instantly stopped by means of the starting lever J_2 which disconnects the positive clutch H_3 between the driving shaft G_3 and pulley K_2.

From this driving shaft, G_3, power is carried through change gears U_2 and bevel and worm gearing to the cross-slide camshaft T_2 on the front of the bed. The carriers V_2, W_2, and B_3 mounted on the camshaft T_2 carry adjustable trip dogs attached at their edges. As the shaft T_2 rotates, these dogs engage trip levers X_2, Y_2, C_3, and D_3 which extend through the bed, causing the levers to throw in clutches on the driving shaft G_3. In this manner the trip dogs on the carrier V_2 may be set to start the turret indexing mechanism at any desired time, and those on W_2 and B_3 to trip the clutches that drive the cams for opening and closing the collet and advancing the bar of stock, and reversing and changing speed of spindle.

Disk Cams Used.—Thin, flat disk cams with a formed edge are used for advancing the three tool slides to the work; one cam for each cross slide, mounted at R_2 and S_2 on shaft T_2, and one for the turret slide at O_2, a set of three cams being required for each job. The turret slide or "lead" cam rotates in unison with the cross-slide cams as the lead camshaft at the end of the bed is connected by bevel gears F_3 with the cross-slide camshaft T_2. The cams are positioned on their shafts by locating pins. Each of the three tool slides is moved to and from the work by a lever, one end bearing on the cam with a roller and the other end having a segment gear engaging a rack on the tool slide. Coil springs in the tool slides force them away from the spindle when the rollers come to a drop on the cam outline.

As the driving shaft G_3 runs at a constant fast speed the movements of advancing the bar of stock, opening and closing the collet, reversing the spindle, indexing the turret, and automatically changing spindle speed are always made at the same rapid rate regardless of the speed at which the spindle is running, and the time of making a piece. Each of these operations is controlled by its own set of adjustable trip dogs so that they are all independent.

The rate at which the tools are fed to the work, and the relative length of time which elapses between the operations of feeding the stock, indexing the turret, reversing the spindle, etc., depend on the speed of the camshaft which is regulated by the combination of change gears U_2. One piece of work, sometimes two or three, is completed in one revolution of the cams, so the gears employed are such as will give a whole, half, or third of a revolution of the camshaft in the number of seconds required to make one piece of the particular work. The time required to make a given piece and the gears to be used are decided upon in connection with plotting the cams for the job.

The bar of stock is gripped by a spring collet or chuck C_2 located at the front of the spindle where it can be removed easily when changing for a different size of stock. The collet does not move endwise but is closed by a taper sleeve which is forced over it.

Stock is pushed through the spindle, when the spring collet is open, by a feed tube having a spring feeding finger screwed into it, the latter located directly behind the spring collet in the nose of the spindle. The feed tube extends to the rear of the spindle, as seen at F_2, where it is connected to a cylinder cam through a slide and levers which automatically move it back and forth in the spindle. These levers are so arranged that by turning the crank H_2 the amount of movement of the tube is varied at will, thus regulating the length of stock pushed through the collet each time. A graduated scale is provided for setting for the required length.

The cams for opening and closing the collet and feeding the stock are both on the same shaft, so the collet is opened, the bar advanced, and the collet closed at the proper time. Stock is fed without stopping the spindle and independently of the other movements.

A tripping arrangement is attached to the stock-feed cam so that when the bar of stock is used up, the starting lever J_2 is automatically thrown over, which stops all the mechanism except the spindle. The chuck is left open for inserting the next bar and a bell I_2 is rung to warn the operator that the machine is idle.

The shaft on which the carrier B_3 is mounted is called the reversing shaft, as it carries the trip dogs for reversing the spindle by throwing the friction clutch E_2. This shaft is connected to the camshaft T_2 by a positive clutch, so it may be disconnected on

work not requiring the reverse, for example, pieces which are not threaded. By using several trip dogs the spindle may be reversed at any time desired on a piece of work.

As such operations as threading often demand a slow cutting speed compared with the turning, drilling, etc., an automatic change of the spindle speed is arranged to provide this. Since the spindle runs independently, changing it from a fast to a slow speed and back again alters the cutting speed but has no effect on the movement of the tools.

The speed change is accomplished by a clutch-and-gear train, tripped by a dog on the carrier B_3, and connected to the overhead works by a rod S_3. This rod shifts the friction-pulley thimble into engagement with a pulley running at a different speed, and does not affect the speed of the driving shaft G_3.

The No. 00 automatic screw machine is not provided with this speed change and on this machine the trip lever C_3 engages the left-hand spindle-driving pulley. On the 0G automatic screw machine lever Y_2 is the one that controls the spindle-speed-changing mechanism.

The vertical turret M_2 (see Fig. 2) is mounted with its axis horizontal, so that with turret and cross-slide tools all working close up to the collet, neither the turret nor the idle tools will interfere with the cross slides. Six holes are provided in the turret for holding tools with shanks. After each operation the turret is swung around to bring the next tool into position by means of the turret change roll Q_3 (Figs. 2*A* and 5) engaging radial slots on the disk P_3 attached to the turret shank. This gives an accelerating and retarding action resulting in very rapid indexing without shock to the machine. The trip lever X_2 (Figs. 2 and 4) controls the indexing.

A taper pin behind the working tool serves to lock the turret in position between indexings, this pin being automatically withdrawn by the indexing mechanism each time. The turret locking pin can be withdrawn by hand with the thumb latch R_3 (Fig. 2*A*) so that tools can be brought to a convenient position for adjusting, also for rotating tools away from line of chuck for removing ends of bars that have been worked up.

The turret slide adjusting screw N_2 (Fig. 2) provides a limited adjustment of the distance between turret and chuck without disturbing the cam lever, when tooling up the machine. The

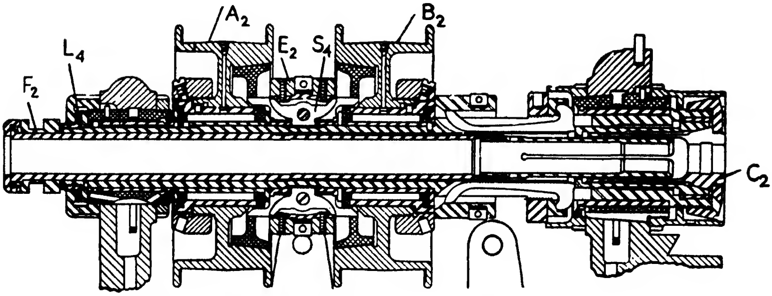


FIG. 3.—Spindle of No. 2 Brown & Sharpe automatic.

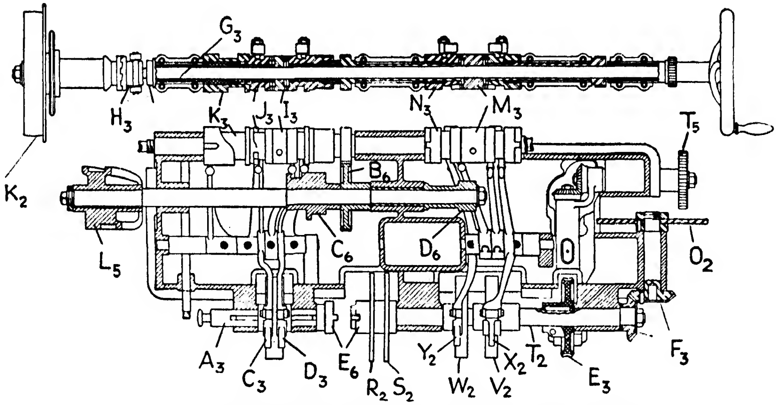


FIG. 4.—Driving shaft, clutches and levers on same machine.

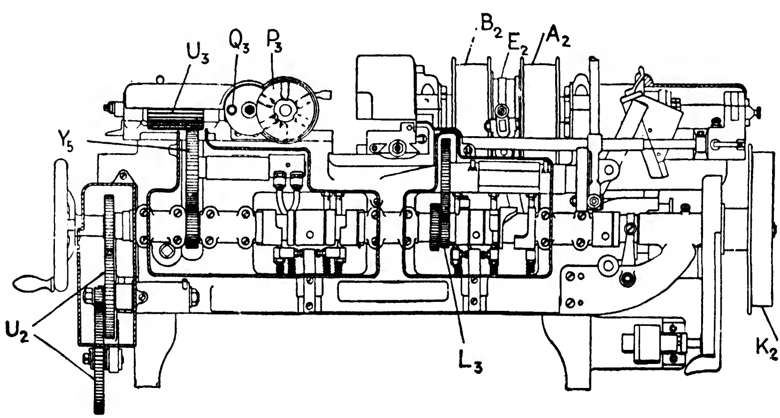


FIG. 5.—Rear elevation of No. 2.

No. 00 automatic screw machine is not provided with this turret adjustment.

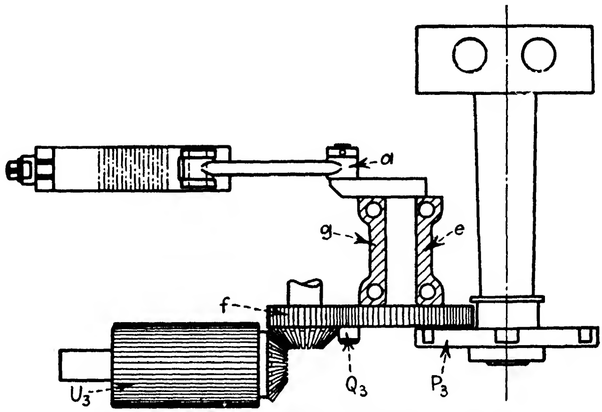


FIG. 6.—Mechanism for indexing turret.

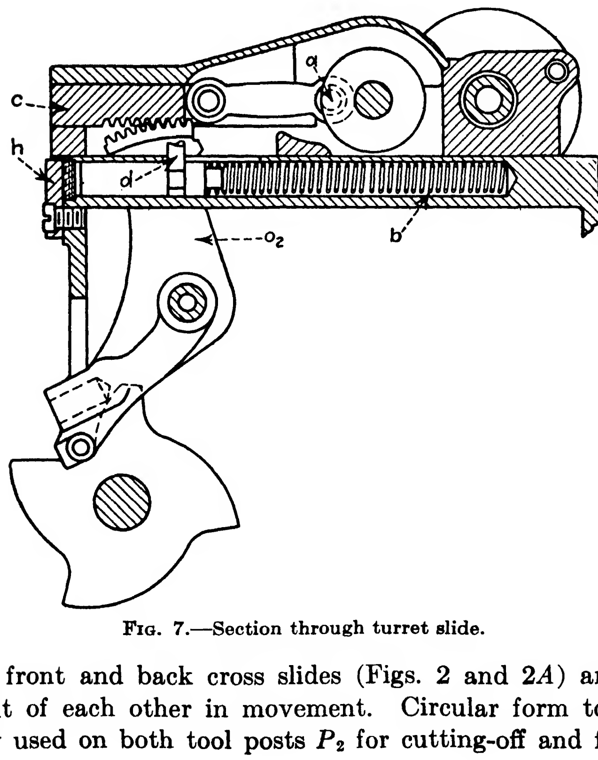


FIG. 7.—Section through turret slide.

The front and back cross slides (Figs. 2 and 2*A*) are independent of each other in movement. Circular form tools are usually used on both tool posts P_2 for cutting-off and forming

operations. These tools can be sharpened without changing their form, like formed milling cutters. Fine adjustment is provided for setting these tools by an adjusting screw Q_2 on each cross slide which moves the slide and tool post toward or from the work without disturbing the cam lever. Stop screws for both slides are provided to insure accuracy in forming. The tool posts can

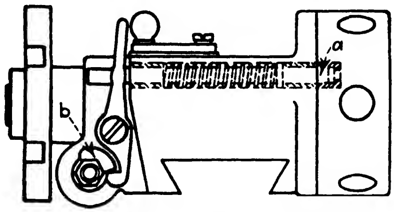


FIG. 8.—Turret locking mechanism.

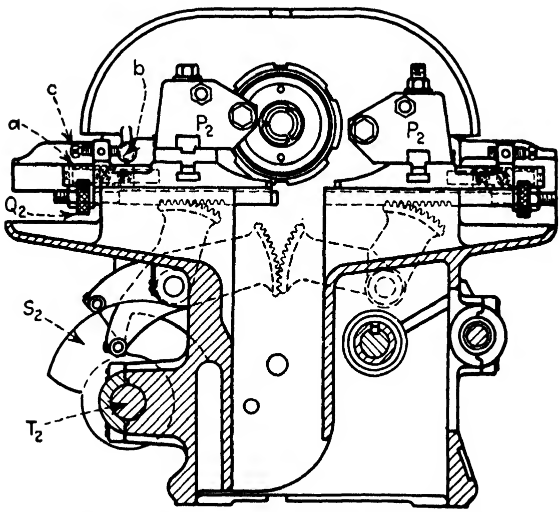


FIG. 9.—Cross slides and how they operate.

also be swiveled slightly to facilitate setting tools. Other styles of tool posts can be substituted in place of either or both of these regular tool posts for circular tools, when straight blade tools for cutting off or other types are to be used.

When setting up the machine the hand wheel L_2 (Fig. 2) is used for turning the feed shaft by hand. Detachable levers are provided for hand operation of the spindle-pulley clutch E_2, the sliding sleeve D_2, which operates the chuck levers, the cross-slide levers R_2 and S_2, and the turret slide.

Details of the spindle, driving shaft, clutches, levers, and their arrangement are shown in the diagrams in Figs. 3, 4, and 5. The indexing mechanism is shown in Fig. 6, a section through the turret slide in Fig. 7, turret locking mechanism in Fig. 8, cross-slide operation in Fig. 9, and other details in Fig. 10.

To prevent the pieces of work, after being cut off, from falling into the chips in the tank table a chute, or deflector, is automatically swung under the piece of work just before it is severed from the bar, guiding it into a strainer pan. A trip dog Z_2 on the carrier W_2 operates this deflector directly.

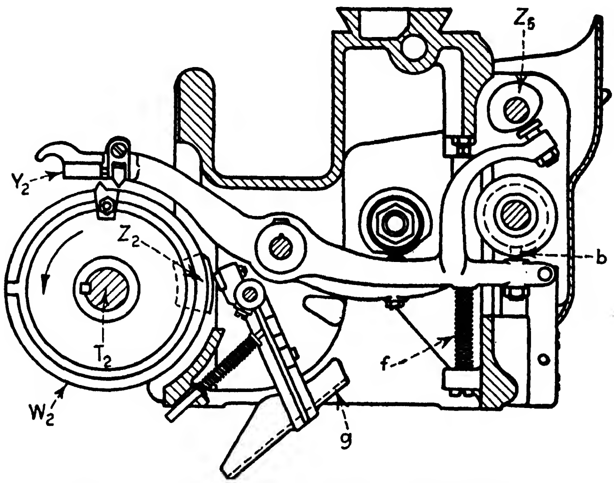


FIG. 10.—Arrangement of levers, clutch, cam etc.

Oil from the collecting reservoir in the tank table is delivered to the tools by the geared pump T_3 (Fig. 2*A*), driven continuously by a chain from the driving shaft pulley K_2. Provision can be made for piping the oil through the turret axis and thence through the tools, when necessary.

On the Brown and Sharpe automatic screw machines with constant-speed drive the principles of operation are the same as already outlined, but there are differences in construction of the drive.

TOOLS AND ATTACHMENTS

The range of usefulness of automatic screw machines can be increased considerably by several standard attachments. These attachments are of two classes.

First are those for performing second operations on the piece of work in a separate mechanism after it is cut off. The screw-slotting, index-drilling, burring, and rear-end-threading attachments are of this type. An operation is automatically accomplished by them while another piece is being produced in the machine spindle, thus eliminating a second machine and usually completing the extra operation without taking additional time.

Second are the attachments used on the machine as tools for special work or auxiliaries to regular tools, all of which operate in conjunction with the usual equipment. Under this head are

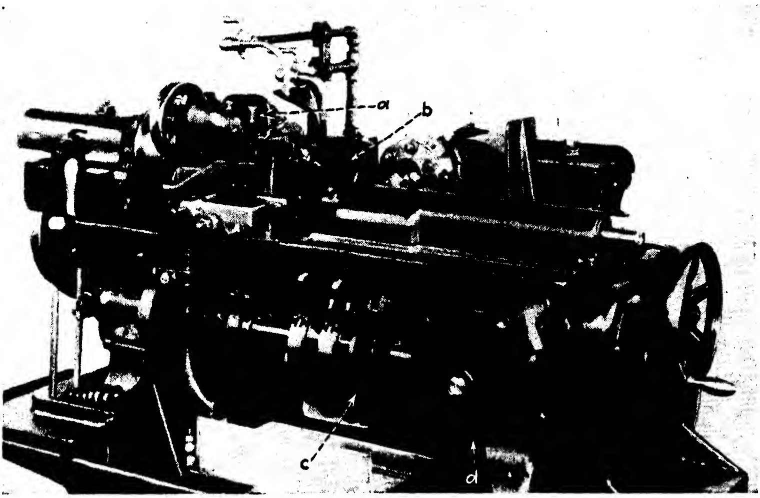


Fig. 11.—Screw-slotting attachment. (*Brown and Sharpe.*)

classed the cross-drilling, drilling, tap- or die-revolving, combination-drilling and tapping, and outside-feeding attachments, the double-movement cross slide, attachment driving stand, and arrangement for oiling through turret tools.

Screw-slotting Attachment.—The screw-slotting attachment, shown in Fig. 11, will take screws or similar pieces as they are cut off by the machine and slot them automatically, thus doing away with an extra machine and slot them automatically, thus doing away with an extra machine for slotting and wholly completing the piece on one machine in practically the same time that is required to make it without slotting. Light milling operations on the piece can be accomplished with this attachment.

A saw *a* is mounted on an adjustable slide and driven from the overhead works by a round belt. The arm *b* takes the piece as it is severed from the bar and transports it to the saw where the slot is cut, and the finished piece is then ejected into the chute leading to the work pan.

Index-drilling Attachment.—The index-drilling attachment (Fig. 12) is designed for drilling radial holes automatically in such work as binding posts, capstan screws, studs, bushings, and pieces of a similar character made in an automatic screw machine.

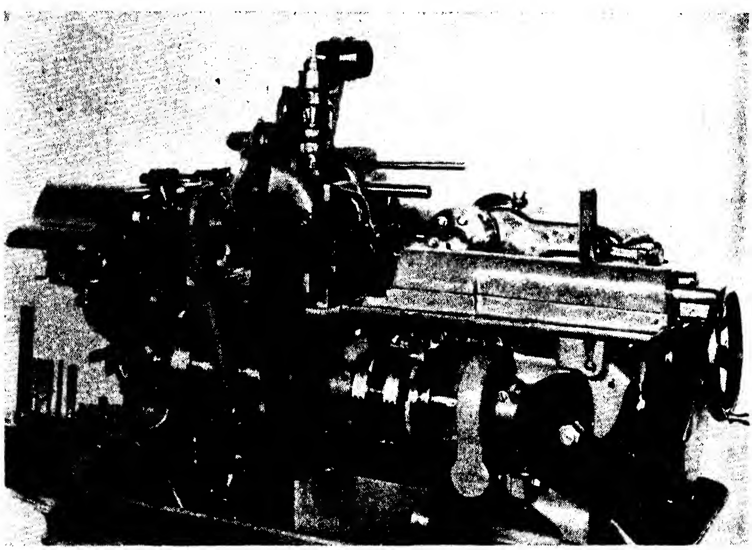


Fig. 12.—Index-drilling attachment.

It does this work during the time the machine is completing the next piece. The attachment consists of a spindle with a spring chuck for holding the work, and a vertical drill spindle driven from the overhead works by a round belt. Cams on the attachment camshaft govern the opening and closing of the chuck, indexing of the work spindle, feeding the drill, and ejecting the piece of work. The piece is transported from the machine spindle and inserted in the attachment chuck by a transporting mechanism identical with that described in connection with the screw-slotting attachment.

The illustrations in Fig. 13 show Brown and Sharpe standard tools and are largely self-explanatory. The adjustable guide

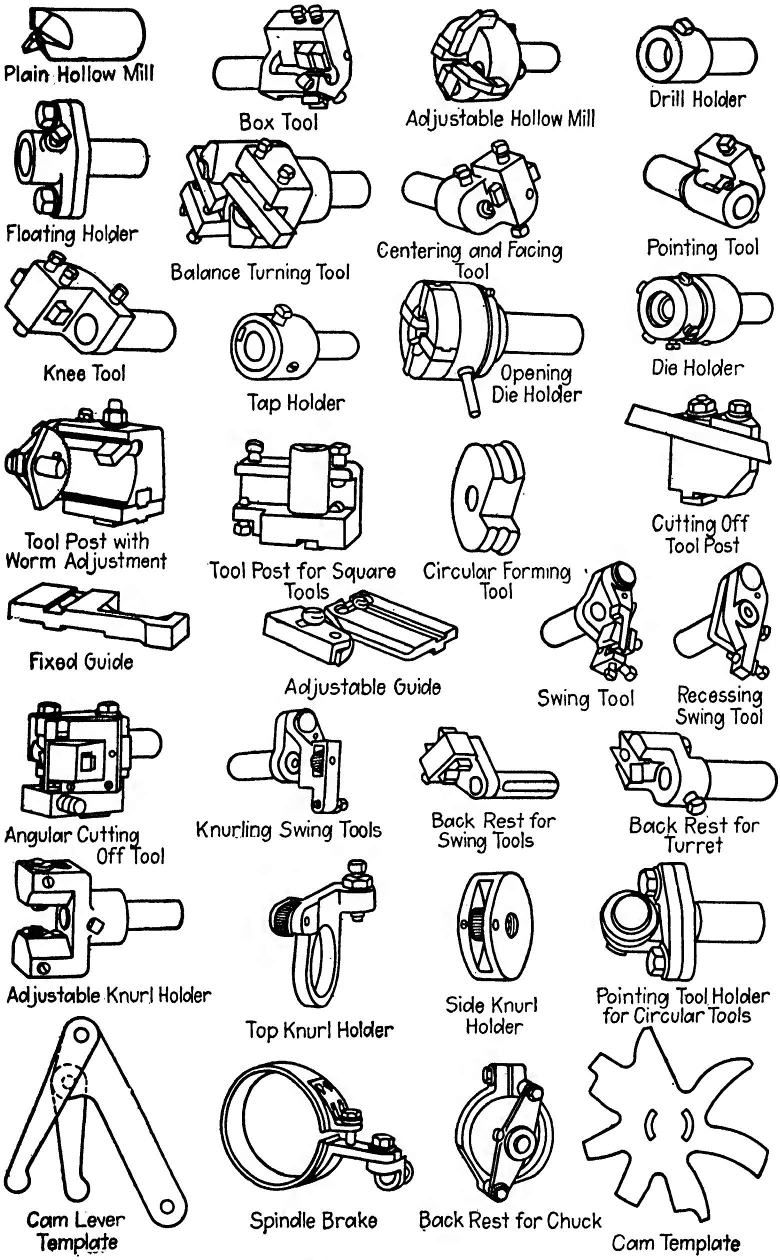


Fig. 13.—Group of standard tools. *(Brown and Sharpe.)*

is for operating a recessing tool (controlling its cut in the work) and for a taper turning-tool guide. It is also for operating the swing tool shown in this group.

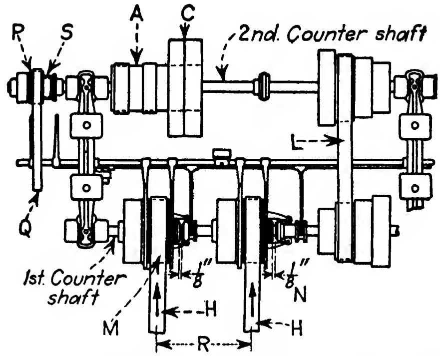


FIG. 14.—Countershafts No. 0 and No. 2 Brown & Sharpe.

Countershaft Drive.—Arrangement of the No. 0 and No. 2 automatic screw-machine drive is as seen in Figs. 14 and 15.

	No. 0 machine	No. 2 machine
Diameter of pulleys *M* and *N*	10 in.	12 in.
Diameter of pulley *P*	6 in.	6 in.
Width of belt *H*	3 in.	3½ in.
Width of belt *Q*	2 in.	2 in.
Width of belt *L*	2¾ in.	3 in.
Width of belt on *S*	1¼ in.	1½ in.
Width of two belts on *A* and *C*	2 in.	2½ in.
Least distance between centers of belts *R*	16 in.	18 in.
Speed of pulley *M*	377 r.p.m.	343 r.p.m.
Speed of pulley *N*	170 r.p.m.	149 r.p.m.
Speed of pulley *P*	300 r.p.m.	340 r.p.m.
Speed of pulleys *A* and *C*	300 r.p.m.	340 r.p.m.
Speed of pulley *G* (Fig. 15)	180 r.p.m.	120 r.p.m.

The single-pulley-drive machines, Nos. 00G, 0G and 2G, may be set ahead or behind the line shaft or simple countershaft. The driving-pulley-belt guard is adjustable to take a belt at any reasonable angle.

In addition to three sizes of screw machines with drive shown, the company manufactures three corresponding sizes equipped

with constant-speed, single-pulley drive. These machines are also made in high-speed types for 30 speeds, the constant-speed-drive machines being designed for motor drive only. All have features of construction in common. There are also two more automatic screw machines in the line, namely, Nos. 4 and 6, which are for handling larger classes of work. Other types of automatic machines in the Brown and Sharpe line are their

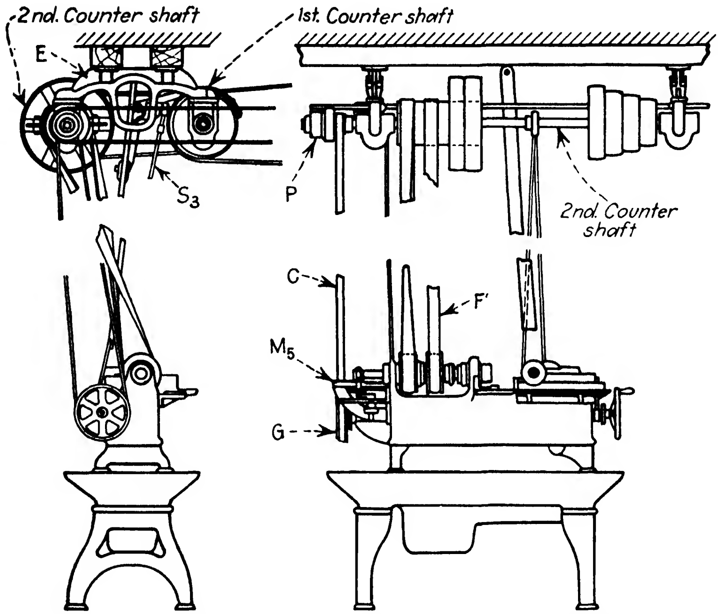


FIG. 15.—Overhead details for No. 0 and No. 2 automatics.

regular automatic turret-forming and automatic cutting-off machines and automatic screw-threading machines (high speed). The capacities of the regular automatic screw machines range from sizes for $\frac{3}{16}$-in. round stock by $1\frac{1}{2}$-in. turning length up to 1-in. stock by 2-in. turning length. Numbers 4 and 6 have, respectively, capacities through outside fingers up to $1\frac{7}{8}$ and $2\frac{3}{8}$ in. and turn lengths up to 4 and 5 in.

CAMMING THE BROWN AND SHARPE AUTOMATIC SCREW MACHINE

The principle of designing cams is to find out the number of spindle revolutions required for each operation and idle move-

ment, overlap those operations and idle movements that can take place simultaneously, and then proportion the balance of spindle revolutions on the surface of the lead cam so that the total of these spindle revolutions equals the full circumference of the cam. Although there are cases where two or more pieces are produced at one revolution of the lead cam, this explanation is devoted especially to such work as requires one revolution to make one piece.

It will be noted that in laying out cams the object is to arrive at the number of hundredths of cam surface required for each operation or idle movement. If necessary, it is possible to split a hundredth into two or three parts to suit requirements at some particular point on the cam.

This section on camming, prepared by the late F. E. Anthony, gives a practical idea of the method employed in laying out the cams for the Brown and Sharpe automatic screw machine. The example taken is a simple screw, made on the No. 00 machine, but the laying out of the cams and the methods employed are practically the same for a more complicated piece, except that the lobes of the cams would necessarily have to be designed to suit the various operations on more complicated work.

Order of Operations.—Assuming that a screw as shown in Fig. 16 is to be made from common yellow brass and the requirements are such that it is necessary to take roughing and finishing cuts to produce the desired blank size before threading, the following order of operations would be selected: rough turn with hollow mill; index turret; finish turn with box tool; index turret; thread; cut-off screw; feed stock to stop; index turret.

The facing of the under side and the removing of the burr on the outer diameter of the head, as well as the indexing of the turret three times to bring the stop into position for feeding the stock for the next blank, are not considered in the above operations, as usually these operations can be performed during the time required for parting the screw from the bar.

The spindle speed, length of cuts, feed per revolution of spindle for the various cuts, the time consumed by the idle movements, such as feeding the stock, indexing the turret, and reversing the spindle, also the clearance between the turret and cross-slide tools, are taken into consideration to determine the total number of revolutions of spindle required for completing the

screw. The fastest spindle speed for the No. 00 machine, which is 2400, can be used for brass. See Tables IX and X. The latter covers surface speed of stock running at different rates of spindle speed.

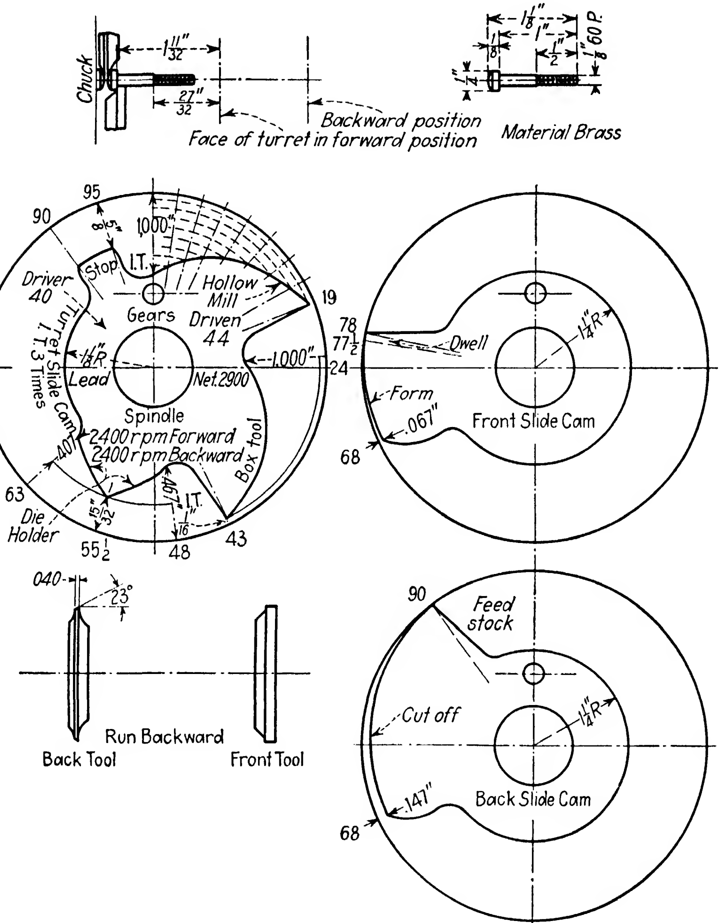


FIG. 16.—Brass screw and cams for making it.

Determining the Number of Spindle Revolutions.—To determine the number of revolutions of the spindle required for the various cuts, divide the length of cut by the feed or advance of the tool per revolution of the spindle. Calculating on a feed of 0.012 in. for roughing, (Table IX), which cut is 1 in. long,

83 revolutions and a fraction of a revolution will be required. As it is not practicable to consider fractions of revolutions, the roughing cut will be given 84 revolutions. After the roughing cut, the turret is indexed to bring the finishing tool into position. The mechanism that rotates the turret maintains a constant speed, and the indexing of the turret, to bring another tool to the cutting point, requires one half second in all cases (see Table XIII[1]). With the spindle running 2400 r.p.m., each change consumes 20 revolutions. It is an advantage, however, to allow extra revolutions for the operation to facilitate adjusting the dogs that control the mechanism; allowing 22 revolutions for the change will give the desired result.

For the finishing cut, which is 1 in. long, and calculating a feed of 0.012 in. per revolution, 8 revolutions will have to be allowed as for roughing.

The pitch of the thread on the screw being 60 per inch, the number of revolutions required for running the die on the screw (which has a thread ½ in. long) will be one half of 60, or 30, actual revolutions. To this amount should be added extra revolutions for clearance; allowing 33 revolutions for running the die on the screw and the same number for backing the die off will give a total of 66 revolutions for threading.

Spindle Revolutions Required during Cross-slide Movements. A certain amount of the cam circle must be allowed between the threading and cutting-off operations, so that the cross-slide tools will not begin to advance to the cutting point until the die holder has dropped back beyond the interfering point. The drop for each cross slide is 1 in., giving a distance of 2 in. from edge to edge of the cross-slide tools, with the slides in the backward position.

The die-holder cap with adjusting screws requires approximately 1½ in. space to pass through; as there are 2 in. between the cross-slide tools, should these tools begin to advance to the cutting point as soon as the die reaches the end of the screw (when backed off), there would be a trifle more clearance than actually required.

Consulting the templet Figs. 17 and 18, it will be noted that 5 hundredths of the cam circle are taken up in advancing the

[1] See Table XI for hundredths of cam surface for feeding stock and indexing turret.

TABLE IX.—APPROXIMATE CUTTING SPEEDS AND FEEDS FOR STANDARD TOOLS

Please bear in mind these figures are only approximate, to be used as a basis from which proper figures for the job in hand may be calculated. They are averages and if the work has any features out of the ordinary take these into consideration and alter the figures accordingly.

Feed—is feed per revolution. Speed—is maximum surface speed of stock in feet per minute.

The same feed is used for both carbon and high-speed steel-cutting tools, the cutting speed only being different.

Tool	Cut		Material							
			Brass free cutting		Mild or soft steel, 0.10–0.20% carbon			Tool steel 0.80–1.00% carbon		
	Width or depth	Dia. of hole	Feed	Speed in surface feet	Feed	Speed in surface feet: Carbon tools	Speed in surface feet: H.S.S. tools	Feed	Speed in surface feet: Carbon tools	Speed in surface feet: H.S.S. tools
Boring tools	0.005	....	......	speed available on machine	0.008	50	110	0.004	30	60
Box tools—roller rest	1/32	....	0.012		0.010	70	150	0.005	40	75
1 Chip finishing	1/16	....	0.010		0.008	70	150	0.004	40	75
	1/8	....	0.008		0.007	70	150	0.003	40	75
	3/16	....	0.008		0.006	70	150	0.002	40	75
	1/4	....	0.006		0.005	70	150	0.0015	40	75
Finishing	0.005	....	0.010		0.010	70	150	0.006	40	75
Center drills	.....	Under 1/8	0.003		0.0015	50	110	0.001	30	75
		Over 1/8	0.006		0.0035	50	110	0.002	30	75
Cut-off tools:										
Angular	.....	....	0.0015		0.0006	80	150	0.0004	50	85
Circular	3/64–1/8	....	0.0035		0.0015	80	150	0.001	50	85
Straight	1/64–1/8	....	0.0035		0.0015	80	150	0.001	50	85
Dia. stock under 1/8 in.	.....	....	0.002		0.0008	80	150	0.0005	50	85
Button dies	.....	....	......		......	30	...	......	14	
Chaser dies	.....	....	......		......	30	40	......	16	20
Drills	.....	0.02	0.0014		0.001	40	60	0.0006	30	45
Twist cut	.....	0.04	0.002		0.0014	40	60	0.0008	30	45
		1/16	0.004		0.002	40	60	0.0012	30	45
		3/32	0.006		0.0025	40	60	0.0016	30	45
		1/8	0.009		0.0035	40	75	0.002	30	60
		3/16	0.012		0.004	40	75	0.003	30	60
		1/4	0.014		0.005	40	75	0.003	30	60
		5/16	0.016		0.005	40	75	0.0035	30	60

		3/8	0.016	Use maximum spindle	0.006	40	85	0.004	30	60
		1/2	0.016		0.006	40	85	0.004	30	60
		5/8	0.016		0.006	40	85	0.004	30	60
Form tools—circular	1/8–1/4		0.002		0.0009 0.0008	80	150	0.0006 0.0005	50	85
	3/8–1/2		0.0015 0.0012		0.0007 0.0006	80	150	0.0004	50	85
	5/8–3/4	....	0.001		0.0005	80	150	0.0003	50	85
	1	....	0.001		0.0004	80	150			
Hollow mills and balance turning tools:										
Turned diam. under 5–32 in.	1/32	....	0.012		0.010	70	150	0.008	40	85
	1/16	....	0.010		0.009	70	150	0.006	40	85
Turned diam. over 5–32 in.	1/32	....	0.017		0.014	70	150	0.010	40	85
	1/16	....	0.015		0.012	70	150	0.008	40	85
	1/8	....	0.012		0.010	70	150	0.008	40	85
	3/16	....	0.010		0.008	70	150	0.006	40	85
	1/4	....	0.009		0.007	70	150	0.0045	40	85
Knee tools	1/64–1/32	....	......		0.010 0.012	70	150	0.010 0.008	40	85
Knurl tools turret	On	....	0.020		0.015	150	...	0.010	105	
	Off	....	0.040		0.030	150	...	0.025	105	
Side or swing	......		0.004		0.002	150	...	0.002	105	
			0.006		0.004	150	...	0.003	105	
Top	......		0.005		0.003	150	...	0.002	105	
			0.008		0.006	150	...	0.004	105	
Pointing and facing tools	......		0.001		0.0008	70	150	0.0005	40	80
			0.0025		0.002	70		0.0008	40	80
Reamers and bits	0.003 to	1/8 or less	0.010–		0.008–	70	150	0.006	40	60
	0.004		0.007		0.006	70	105	0.004	40	60
	0.004 to	1/8 or over	0.010		0.010	70	105	0.006	40	60
	0.008							0.008	40	60
Recessing tools, end cut	....		0.001		0.0006	70	150	0.0004	40	75
			0.005		0.003	70	150	0.002	40	75
Inside cut	1/16–1/8		0.0025		0.002	70	105	0.0015	40	60
			0.0008		0.0006	70	105	0.0004	40	60
Swing tools, forming	1/8–1/4		0.002		0.0007	70	150	0.0005	40	85
			0.0012		0.0005	70	150	0.0003	40	85
	3/8–1/2		0.001		0.0004	70	150	0.0002	40	85
			0.0008		0.0003					
Turning straight	1/32	....	0.008		0.006	70	150	0.0035	40	85
	1/16	....	0.006		0.004	70	150	0.003	40	85
	1/8	....	0.005		0.003	70	150	0.002	40	85
	3/16	....	0.004		0.0025	70	150	0.0015	40	85
Taps	......	....	......		......	25	30	......	12	15
Swing tools										

Taper turning same as straight turning but the feed is taken slow enough for the greatest depth of cut.

TABLE X.—SURFACE SPEED OF WORK IN FEET PER MINUTE

Revolutions per minute

Diam. of stock	48	57	68	80	98	116	120	140	168	180	200	225	260	280	300
1/16															
5/64															
3/32															
7/64															
1/8															10
9/64													10	10	11
5/32													11	11	12
11/64												10	12	13	14
3/16											10	11	13	14	15
13/64										10	11	12	14	15	16
7/32									10	10	11	13	15	16	17
15/64									10	11	12	14	16	17	18
1/4									11	12	13	15	17	18	20
9/32								10	12	13	15	17	19	21	22
5/16							10	11	14	15	16	18	21	23	25
11/32						10	11	13	15	16	18	20	23	25	27
3/8					10	11	12	14	16	18	20	22	26	28	30
13/32					10	12	13	15	17	19	21	24	28	30	32
7/16					11	12	13	16	19	21	23	27	30	32	34
15/32				10	12	14	15	17	20	22	25	28	32	34	37
1/2				10	13	14	16	18	22	24	26	29	34	37	39
9/16			10	12	14	17	18	21	25	27	29	33	38	41	44
5/8			11	13	16	19	20	23	28	30	33	37	43	46	49
11/16		10	12	14	18	21	22	25	30	32	36	40	47	50	54
3/4		11	13	16	19	23	24	28	33	35	39	44	51	55	59

Diam. of stock	342	385	445	492	540	560	614	665	735	790	850	928	973	1087	1140
1/16							10	11	12	13	14	15	15	19	19
5/64				10	11	12	13	14	15	16	17	19	20	22	23
3/32		10	11	12	13	14	15	16	18	19	21	23	24	27	28
7/64	10	11	13	14	15	16	18	19	21	23	24	26	28	31	33
1/8	11	13	15	16	17	18	20	22	24	26	28	29	32	35	37
9/64	13	14	16	18	20	21	23	24	27	29	31	34	36	40	42
5/32	14	16	18	20	22	23	25	27	30	32	35	38	40	45	47
11/64	15	17	20	22	24	25	28	30	33	35	38	42	44	49	51
3/16	17	19	22	24	26	27	30	33	36	39	42	45	48	54	56
13/64	18	20	24	26	29	30	33	35	39	42	45	49	52	58	60
7/32	20	22	26	28	31	32	35	38	42	45	49	53	56	62	65
15/64	21	24	27	30	33	34	38	41	44	48	52	57	60	66	70
1/4	22	25	29	32	35	37	40	44	47	52	56	61	64	71	75
9/32	25	28	33	36	40	41	45	49	54	58	63	69	72	80	84
5/16	28	31	36	40	44	46	50	55	60	65	70	76	79	89	93
11/32	31	35	40	44	48	50	55	60	66	71	77	83	87	98	102
3/8	34	38	44	48	53	55	60	66	72	78	84	91	96	108	112
13/32	36	41	48	52	57	60	65	71	78	84	91	99	103	116	121
7/16	39	44	51	56	62	64	70	76	84	91	98	107	111	125	131
15/32	42	47	55	60	66	69	75	82	90	97	104	114	120	134	140
1/2	45	50	58	64	70	73	80	87	96	103	111	121	127	142	149
9/16	50	57	66	73	80	83	90	98	105	116	125	137	143	160	168
5/8	56	63	73	81	89	92	101	109	120	129	139	152	159	178	186
11/16	61	69	80	89	97	101	111	120	132	142	153	167	175	195	205
3/4	67	76	87	97	106	110	120	130	144	155	167	182	191	213	224

Diam. of stock	1200	1285	1492	1748	1800	2062	2400	2600	2700	3100	3500	3600	3700	4300	5000
1/16	20	21	24	28	29	34	39	42	44	51	57	59	60	70	82
5/64	25	26	30	36	37	42	49	54	56	65	73	75	77	90	104
3/32	29	32	37	43	44	51	59	64	66	76	86	88	91	106	123
7/64	34	37	43	50	52	59	69	74	77	88	99	102	105	122	142
1/8	39	42	49	57	59	68	78	85	88	102	115	118	121	141	164
9/64	44	47	55	64	66	76	88	95	99	114	128	132	135	158	183
5/32	49	53	61	72	74	85	98	106	110	127	143	147	151	176	204
11/64	54	58	67	79	81	93	108	117	121	140	157	162	166	193	225
3/16	59	63	73	86	88	102	118	127	132	152	172	177	181	211	245
13/64	64	68	79	93	96	110	128	138	144	165	186	192	197	229	267
7/32	69	74	85	100	103	119	138	149	154	178	200	207	211	246	286
15/64	73	79	91	107	110	128	147	158	164	189	213	219	225	262	304
1/4	79	84	97	114	118	136	157	170	176	203	229	237	242	281	327
9/32	88	93	110	129	133	152	177	191	199	228	258	264	272	316	368
5/16	98	106	122	143	147	169	196	213	221	254	286	294	302	351	408
11/32	108	115	134	157	162	185	216	234	243	279	315	324	333	387	450
3/8	118	127	147	171	177	202	236	255	265	304	344	354	363	422	490
13/32	128	137	158	186	191	219	255	276	287	330	372	384	393	457	532
7/16	138	148	171	200	206	236	275	298	309	355	400	414	424	493	
15/32	147	158	183	215	221	253	295	319	332	380	430	441	455	528	
1/2	157	168	195	229	236	270	314	340	353	406	458	471	485	563	
9/16	177	189	219	257	265	303	353	382	397	456	514	531	544		
5/8	196	210	244	286	295	337	393	425	442	507	572	588			
11/16	216	231	268	315	324	371	432	468	486	558	628				
3/4	236	252	292	342	353	404	472	510	530	608					

TABLE X.—SURFACE SPEED OF WORK IN FEET PER MINUTE.—(*Continued*)

Diam. of stock	Revolutions per minute																																											
	48	57	68	80	98	116	120	140	168	180	200	225	260	280	300	342	385	445	492	540	560	614	665	735	790	850	928	973	1087	1140	1200	1285	1492	1748	1800	2062	2400	2600	2700	3100	3500	3600	3700	4300	5000
13/16	10	12	14	17	21	25	26	30	35	38	43	48	55	60	64	73	82	95	105	115	120	131	142	156	168	181	197	207	231	243	255	273	317	372	383	438	510	553	574						
7/8	11	13	16	18	23	27	28	32	38	41	46	52	60	65	69	79	89	102	113	124	129	141	152	168	181	195	212	223	249	261	275	294	342	400	413	472	550	595	619						
15/16	12	14	17	20	24	28	30	33	41	44	49	55	64	69	74	84	94	109	120	132	138	151	163	180	194	209	227	239	267	280	295	315	366	429	442	506	590	637							
1	13	15	18	21	26	29	32	36	44	47	52	58	68	73	78	89	100	116	128	141	147	160	174	193	206	223	242	254	284	299	314	337	390	458	471	540	628	681							
1 1/8	14	17	20	23	29	34	35	41	48	53	58	65	76	82	88	100	112	130	144	159	164	180	195	216	232	250	273	286	320	335	353	379	438	514	530	606	706								
1 1/4	16	19	22	26	32	38	39	46	54	59	65	74	85	92	98	112	126	146	161	177	183	200	218	240	259	278	303	319	355	373	393	420	488	572	588	675									
1 3/8	17	21	25	29	35	42	43	50	60	65	72	81	94	101	108	123	139	160	177	194	202	221	239	264	284	306	333	350	391	409	432	462	536	629											
1 1/2	19	22	27	32	39	46	47	55	66	71	79	89	102	110	118	135	152	174	193	212	220	241	261	289	310	334	364	382	427	448	471	505	586												
1 5/8	21	25	29	35	42	50	52	60	72	78	86	97	112	121	130	148	164	189	209	229	238	261	283	312	336	361	394	414	461	485	510	546													
1 3/4	22	26	31	37	45	53	55	64	76	82	92	103	119	128	138	157	177	204	225	247	257	281	304	336	362	389	424	446	497	522															
1 7/8	23	28	33	39	48	57	59	68	81	88	98	110	127	137	146	168	189	218	242	265	275	301	326	360	387	417	455	478	533																
2	25	30	36	42	51	61	63	73	88	94	105	118	136	148	157	179	202	233	257	283	293	321	348	384	413	445	485	509																	
2 1/8	27	32	38	45	55	65	68	79	93	101	112	127	146	156	167	190	214	247	273	300	312	341	370	408	439	473	515	540																	
2 1/4	28	34	40	47	58	69	71	83	99	106	118	133	153	165	177	202	227	262	290	318	330	362	392	433	465	502	546																		
2 3/8	30	35	42	50	61	72	75	87	104	112	124	140	162	174	187	213	240	277	306	336	348	382	413	457	490	528	576																		
2 1/2	32	37	45	52	64	76	78	92	110	118	131	147	170	184	196	224	252	291	322	354	367	402	435	480	516	555																			

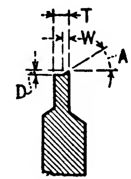
Surface feet per minute

TABLE XI.—HUNDREDTHS OF CAM SURFACE FOR FEEDING STOCK AND INDEXING TURRET (APPROXIMATE)

Time to make one piece, sec.	Hundredths of cam surface to feed stock			Hundredths of cam surface to index turret					
	Machine			00 and 00G machine		0 and 0G machine		2 and 2G machine	
	00 00G	0 0G	2 2G	Roll dropped ⅝ in. from full height of cam	Roll dropped 1¼ in. from full height of cam	Roll dropped 1 in. from full height of cam	Roll dropped 2 in. from full height of cam	Roll dropped 1½ in. from full height of cam	Roll dropped 3 in. from full height of cam
3	17								
4	13								
5	10	14							
6	9	12	17						
7	8	10	15						
8	7	9	13						
9	6	8	12						
10	5	8	10						
11	5	7	10						
12	5	6	9						
13	4	6	9						
14	4	5	8						
15	4	5							
16	4	5	7	...	...	...	7½		
17	3	4	..	...	5½	...	7½		
18	3	4	6	...	5½	...	7½		
19	3	4	..	...	5½	...	7½		
20	3	4	5	...	5½	...	5½	..	10
21	3	..	..	3	5½				
22	3	4	5	3	5½	...	5½	..	10
23	3	..	..	3	5½				
24	3	3	5	3	5½	...	5½	..	10

25	3	..	..		3	5½				
26	3	3	4		3	5½	...	5½	..	10
27	3	..	..		3	5½				
28	3	3	4		3	5½	...	5½	..	10
29	3	..	..		3	5½				
30	3	3	4		3	5½	3	5½	..	10
32	3	3	..		3	5½	3	5½		
34	3	3	..		3	5½	3	5½		
35	..	..	4		...	...	...	...	4	10
36	3	3	..		2½	4	3	5½		
38	3	3	..		2½	4	3	5½		
40	3	3	3		2½	4	3	5½	3	5½
42	3	..	..		2½	4	3	5½		
44	3	3	..		2½	4	3	5½		
45	..	..	3		...	...	...	...	3	5½
46	3	..	..		2½	4	3	5½		
48	3	3	..		...	4	3	5½		
50	3	..	3		2½	4	3	5½	3	5½
52	3	3	..		2½	4	3	5½		
54	3	..	..		2½	4	3	5½		
55	..	..	3		...	...	...	...	3	5½
56	3	3	..		2½	4	3	5½		
58	3	..	..		2½	4	3	5½		
60	3	3	3		2½	4	2½	4½	3	5½
63	3	..	..		2½	4				
65	..	3	..		...	...	2½	4½		
70	3	3	3		2½	4	2½	4½	3	5½
75	..	3	..		...	...	2½	4½		
77	3	..	..		2½	4				
80	..	3	3		...	...	2½	4½	3	5½
84	3	..	..		2½	4				
90	..	3	3		...	...	2½	4½	3	5½
91	3	..	..		2½	4				
100	..	3	3		...	...	2½	4½	3	5½
110	..	3	3		...	...	2½	4½	3	5½
120	..	3	3		...	...	2½	4½	3	5½
135	..	3	3		...	...	2½	4½	3	5½
150	..	3	3		...	...	2½	4½	3	5½
165	..	3	3		...	...	2½	4½	3	5½
180	..	3	3		...	...	2½	4½	2	4
195–390	..	3	3		...	...	2½	4½	2	4
390–480	..	..	3						2	4

TABLE XII.—ANGLES AND THICKNESSES FOR CIRCULAR CUTTING-OFF TOOLS



W **is same as** ***T*** **up to 0.060** in. inclusive.
W **is same as one half** *T* from 0.070 to 0.120 in. thickness inclusive.
W **is 0.060** for 0.140 in. thickness and over.
A **is 23°** when cutting brass, aluminum, copper, silver and zinc.
A **is 15°** when cutting steel, iron, bronze, and nickel.
Least thickness used when cutting off into tapped holes is the lead of two and one half threads plus 0.010 in.
Least thickness used when cutting off into reamed holes smaller than 1/8 in. diameter is 0.040 in.
Thickness used when cutting off tubing is two thirds *T* as given below for corresponding diameters.
Thickness used when angles or radii start from outside diameter of tool is governed by varying conditions and determined accordingly.

Diameter of stock	1/16	3/32	1/8	3/16	1/4	5/16	3/8	7/16	1/2 to 9/16	5/8 to 3/4	13/16 to 1	1 1/16 to 1 5/16	1 3/8 to 1 7/8	2 to 2 1/2
Thickness *T*	0.020	0.030	0.040	0.050	0.060	0.070	0.080	0.090	0.100	0.120	0.140	0.160	0.190	0.220
Depth of angle *D*														
For brass	0.0085	0.013	0.017	0.0215	0.0255	0.015	0.017	0.019	0.0215	0.0255	0.0255	0.0255	0.0255	0.0255
For steel	0.0055	0.008	0.011	0.0135	0.016	0.0095	0.011	0.012	0.0135	0.016	0.016	0.016	0.016	0.016

cross slide from its backward position (which is determined by the low portion of the cam) to the point where the tool commences the cut. The revolutions of the spindle during this clearance can be determined after finding the total revolutions required for the different operations and idle movement. The cutting-off tool, as shown in Fig. 16, is arranged with a parting blade that has a 23-deg. angle on the cutting edge as in Table XII; this is for the purpose of making the parting close to the head of the screw, to avoid leaving a large teat on the piece when dropped. Using an angular blade, it is necessary to allow extra travel so that the low point of the angle can be carried a trifle by the

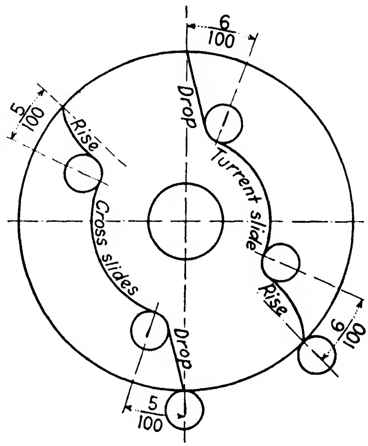


Fig. 17.—Use of cam templet.

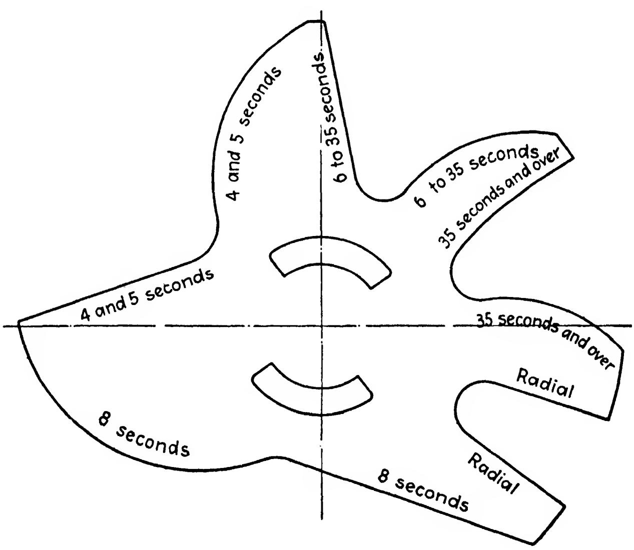
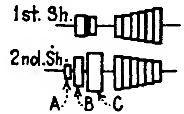


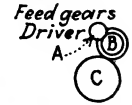
Fig. 18.—No. 00 cam templet.

center of the spindle to insure removing the teat on the bar, which is termed "by-travel." Adding to the radius (0.125 in.)

TABLE XIII.—FOR LAYING OUT CAMS FOR BROWN AND SHARPE NO. 00 AUTOMATIC SCREW MACHINE

Belt on		
Spindle speeds		
*A	*B	C
420	792	1087
492	927	1273
576	1087	1492
675	1273	1748
792	1492	2048
927	1748	2400





Spindle speeds 420 / 3.5	492 / 4.1	576 / 4.8	675 / 5.6	792 / 6.6	927 / 7.7	1087 / 9.1	1273 / 10.6	1492 / 12.4	1748 / 14.6	2048 / 17.1	2400 / 20.	min. / ½ sec.	Time to make one piece, sec.	Gross product per hour	Net product per hour gross minus 10%	Gear on A	1st gear on B	2nd gear on B	Gear on C
Number of revolutions to make one piece																			
21	25	29	34	40	46	54	64	75	87	102	120		3	1200	1080	70	..	..	21
24	29	33	39	46	54	64	74	87	102	119	140		3.5	1028	920	60	..	..	21
28	33	38	45	53	62	72	85	99	117	137	160		4	900	810	50	..	..	20
31	37	43	51	59	69	82	96	112	131	153	180		4.5	800	720	44	..	..	20
35	41	48	56	66	77	91	106	124	146	171	200		5	720	640	60	..	..	30
38	45	53	62	73	85	100	117	137	160	188	220		5.5	654	580	54	..	..	30
42	49	58	67	79	93	109	127	149	175	205	240		6	600	540	50	..	..	30
45	53	62	73	86	100	118	138	161	189	222	260		6.5	554	490	52	..	..	34
49	57	67	79	92	108	127	149	174	204	239	280		7	514	460	60	..	..	42
52	61	72	84	99	116	136	159	186	219	256	300		7.5	480	430	56	..	..	42
56	66	77	90	106	124	145	170	199	233	273	320		8	450	400	60	..	..	48
60	70	82	95	112	131	154	180	211	248	290	340		8.5	423	380	40	..	..	34
63	74	86	101	119	139	163	191	224	262	307	370		9	400	360	60	..	..	54
67	76	91	107	125	147	172	202	236	277	324	380		9.5	379	340	40	..	..	38
70	82	96	112	132	154	181	212	249	291	341	400		10	360	320	40	..	..	40
77	90	106	124	145	170	199	233	274	320	375	440		11	327	290	40	..	..	44
84	98	115	135	158	185	217	255	298	350	410	480		12	300	270	40	..	..	48
91	107	125	146	172	201	236	276	323	379	444	520		13	276	250	40	..	..	52
98	115	134	157	185	216	254	297	348	408	478	560		14	257	230	30	..	..	42
105	123	144	169	198	232	272	318	373	437	512	600		15	240	210	40	..	..	60
112	131	154	180	211	247	290	339	398	466	546	640		16	225	200	30	..	..	48
119	139	163	191	224	263	308	361	423	495	580	680		17	211	190	20	..	..	34
126	148	173	202	238	278	326	382	448	524	614	720		18	200	180	30	..	..	54
133	156	182	214	251	294	344	403	472	554	649	760		19	189	170	20	..	..	38
140	164	192	225	264	309	362	424	497	583	683	800		20	180	160	20	..	..	40
147	172	202	236	277	324	380	446	522	612	717	840		21	171	150	20	..	..	42
154	180	211	247	290	340	399	467	547	641	751	880		22	163	145	20	..	..	44
161	189	221	259	304	355	417	488	572	670	785	920		23	156	140	20	..	..	46

168	197	230	270	317	371	435	509	597	699	819	960		24	150	135	20	..	..	48
175	205	240	281	330	386	453	530	622	728	853	1000		25	144	130	20	..	..	50
182	213	250	292	343	402	471	552	647	757	887	1040		26	138	125	20	..	..	52
189	221	259	304	356	417	489	573	671	787	922	1080		27	133	120	20	..	..	54
196	230	269	315	370	433	507	595	696	816	956	1120		28	128	115	20	..	..	56
203	238	278	326	383	448	525	615	721	845	990	1160		29	124	110	20	..	..	58
210	246	288	337	396	463	543	636	746	874	1024	1200		30	120	105	20	..	..	60
224	262	307	360	422	494	580	679	796	932	1092	1280		32	112	100	30	30	48	60
238	279	326	383	449	525	616	721	846	990	1161	1360		34	105	95	20	44	50	60
252	295	346	405	475	556	652	764	895	1049	1229	1440		36	100	90	30	30	54	60
266	312	365	428	502	587	688	806	945	1107	1297	1520		38	94	85	20	30	38	60
280	328	384	450	528	618	724	849	995	1165	1365	1600		40	90	80	20	30	40	60
294	344	403	473	554	649	761	891	1045	1224	1434	1680		42	85	77	20	30	42	60
308	361	422	495	581	680	797	934	1094	1282	1502	1760		44	81	72	20	30	44	60
322	377	442	518	607	711	833	976	1144	1340	1570	1840		46	78	70	20	30	46	60
336	394	461	540	634	742	870	1018	1194	1398	1638	1920		48	75	67	20	30	48	60
350	410	480	563	660	773	906	1061	1243	1457	1707	2000		50	72	65	20	30	50	60
364	426	499	585	686	803	942	1103	1293	1515	1775	2080		52	69	62	20	30	52	60
378	443	518	608	713	834	978	1146	1343	1573	1843	2160		54	66	60	20	30	54	60
392	459	538	630	739	865	1015	1188	1393	1631	1911	2240		56	64	57	20	30	56	60
406	476	557	653	766	896	1051	1231	1442	1690	1980	2320		58	62	55	20	30	58	60
420	492	576	675	792	927	1087	1273	1492	1748	2048	2400		60	60	52	30	21	54	70
441	517	605	709	832	973	1141	1337	1567	1835	2150	2520		63	57	50	30	20	54	70
490	574	672	788	924	1082	1268	1485	1741	2039	2389	2800		70	51	45	20	20	40	70
539	631	739	866	1016	1190	1395	1634	1915	2243	2628	3080		77	46	42	20	20	44	70
588	689	806	945	1109	1298	1522	1782	2089	2447	2867	3360		84	42	38	20	20	48	70
637	746	874	1024	1201	1406	1649	1931	2263	2651	3106	3640		91	39	35	20	20	52	70

NOTE: Similar tables are published by Brown and Sharpe to cover all sizes of their automatic screw machines including high-speed and H.S. 30 speed machines and automatic threading machines, forming machines and cutting-off machines.

of the bar used 0.019 in., the amount of by-travel required for the cutting-off tool plus 0.003 in. clearance to allow for variations in material, a total of 0.147 in. travel for the cutting-off tool is obtained; considering a feed or advance of 0.0015 in. per revolution, approximately 97 revolutions will be required for cutting off.

The facing of the under side of the head (the tool for which travels from ¼ in. diameter of stock to ⅛ diameter of finished size) requires a travel of 0.067 in., including clearance to allow for variation in material; this cut carried at a feed of 0.0016 in. will require approximately 42 revolutions. As this cut can begin at the same time as the cutting-off operation and will be completed by the time the screw is partially cut off, the revolutions required need not be considered when determining the total number.

Indexing and Stock-feeding Allowance.—As there are but four turret tools used in making the screw, it will be necessary to index the turret three times after the threading operation to bring the stop into position for feeding the stock for the following screw. The 97 revolutions allowed for cutting off will give ample time for these changes.

An allowance of 22 revolutions must be added for feeding the stock to the stop after cutting off and indexing the turret, to bring the roughing tool into position for the following screw.

The following tabulation shows the total number of revolutions required for actual operations:

	Revolutions
Roughing cut	84
Index cut	22
Finishing cut	84
Index cut	22
Threading	66
Clearance	..
Cutting off	97
(Index turret three times; face under side of head)	
Feed stock	22
Index turret	22
	419

As 5 hundredths of the cam circle must be allowed for clearance between the die holder and cross-slide tools, the above total of

419 revolutions represents 95 hundredths of the cam circle. Dividing 419 by 95, the quotient, 4.41 (the number of revolutions in 1 hundredth), multiplied by 100 gives a total of 441 revolutions of the spindle to complete the screw.

Selecting Change Gears.—With each machine a number of change gears are furnished to allow the camshaft speeds to be varied from 3 to 91 sec. per revolution. As the spindle makes 40 revolutions per second selecting a train of gearing from the gear table (see Table XIII), accompanying the machine, that will give a revolution of the camshaft in 11 sec., the spindle will make 440 revolutions to one of the camshaft. It will, therefore, be necessary to take away a revolution from one of the operations, the total being 441. Allowing 96 revolutions for cutting off, instead of 97, as previously calculated upon, will not make any material difference to the feed for this cut.

Division of the Cam Circle.—As it is not convenient to divide the cam blanks into various numbers of parts equal to the number of revolutions required for making different pieces, it is the general practice to divide the cam circle into 100 equal parts, as shown in Fig. 19. The number of hundredths for the lobes and spaces on the cams is obtained by dividing the number of revolutions for each operation by the total number, taking the nearest decimal with two places. For example: The number of revolutions for the roughing cut is 84; dividing 84 by 440, the result, 0.19, is the number of hundredths of the cam circle required for the first cut. Reducing the remainder of the operations in the same manner the cam circle is divided as follows:

	Revolutions	Hundredths
Rough turn	84	19
Index turret	22	5
Finish turn	84	19
Index turret	22	5
Thread	66	15
Clearance	22	5
Cut off	96	22
Feed stock to stop	22	5
Index turret	22	5
Total	440	100

Turret and Cross-slide Cams.—Commencing at the line opposite the ¼-in. hole in the cam blank, as shown in Fig. 16, the turret-slide cam is divided as follows:

0 to 19, lobe for roughing cut;
19 to 24, space for indexing turret;
24 to 43, lobe for finishing cut;
43 to 48, space for indexing turret;
48 to 63, lobe for threading;
63 to 90, reduced to diameter (2¼ in.) of cam carrier, allowing turret to dwell in rear position during the time taken up for clearance and the cutting-off and facing operation;
90 to 95, lobe for feeding stock;
95 to 0, space for indexing turret.

A clearance of 5 hundredths has been calculated on after threading to avoid interference of the cross-slide tools with the die holder, in which case the cross-slide cam for cutting off will commence at 68 and extend to 90. The parting of the piece from the bar will occur before the complete portion of the lobe has passed the roll on the cross-slide lever, owing to the extra amount of throw on the cam necessary for removing the teat on the bar which has previously been termed by-travel. In this case the stop for feeding the stock can be in position as soon as the cutting-off tool commences to drop back after cutting off. The travel of the facing tool, which commences at ¼ diameter and is carried forward to ⅛ diameter, will be approximately 0.067 in., including clearance; advancing the tool at 0.0016 in. per revolution, 42 revolutions will be required. To this number are added 2 revolutions for dwell of the tool at the finishing point, making a total of 44 revolutions, which takes up 10 hundredths of the cam circle. As 2 revolutions for dwell will require ½ hundredth, the throw of 0.067 in. will take 9½ hundredths of cam surface.

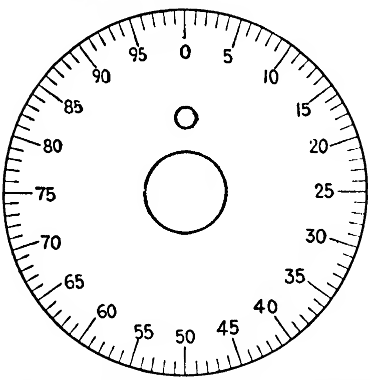


Fig. 19.—Graduated index for laying out cams.

The facing operation commences at the same time as the cutting-off; consequently the spacing of the front-slide cam will be from 68 to 77½ for advance of tool, 77½ to 78 for dwell.

The height of the various cam lobes is determined by the lengths of the tools to be used. The face of the turret is approximately 1⅝ in. from the face of the chuck, with the turret-slide lever on a cam portion 4½ in. diameter.

Tool Layout.—On the cam layout sheet, Fig. 16, three perpendicular, parallel lines, approximately 1 in. long, should be drawn, with a distance of 1⅝ in. between the first and second, and 1⅛ in. between the second and third lines. The first line represents the face of the chuck; the second, the face of the turret with the lever on a cam 4½ in. diameter; and the third, the face of the turret with the slide in the rear position. A line drawn at right angles through the center of these lines represents the center of the spindle. The cross-slide tools and sample should be drawn to scale close to the chuck line. The line representing the center of the spindle is necessarily the center of the piece to be made. The roughing and finishing cuts are carried close to the under side of the head of the screw. The hollow mill and the head portion of its holder, which extends beyond the face of the turret, is 1⅜ in. long as shown in Fig. 16; as the under side of the head is approximately 1 11/32 in. from the line, representing the face of the turret in the forward position on a 4½-in. cam diameter, it will be necessary to arrange for the high point on the lobe to stop at least 1/32 in. below the 4½-in. circle on the layout sheet, so that the cut will not be carried forward to such a point that the proper thickness of head cannot be obtained. An extra thirty-second of an inch should be allowed to facilitate adjusting the tool, in which case the high point of the roughing lobe should stop 1/16 in. below the 4½-in. circle; as the rise on that lobe is 1 in. (the length of the cut), the low point will be 1 1/16 in. below the 4½-in. circle.

Turret-slide Cam Lobes.—From the zero line to 19 hundredths of the cam circle, construct an increase curve, with a rise of 1 in. for the roughing cut. The method of laying out the increase curve, approximately, is shown in Fig. 16. With a templet as shown in Figs. 17 and 18 draw the line of drop, beginning at 19 hundredths, and draw an arc equal to the radius (¼ in.) of the turret-slide lever roll, tangent to the drop line, with the low

point of the arc about $\frac{1}{16}$ in. below the starting point of the following lobe. The lobe for the finishing cut is a duplicate of the roughing.

In constructing the threading lobes, it is the usual practice to allow the die head, which is arranged to slide on the holder, to draw away from the turret to prevent crowding the die on to the work.

As 33 revolutions are allowed for running the die on to the screw, the advance of the die would be $\frac{33}{60}$ (0.550 in.). From this,

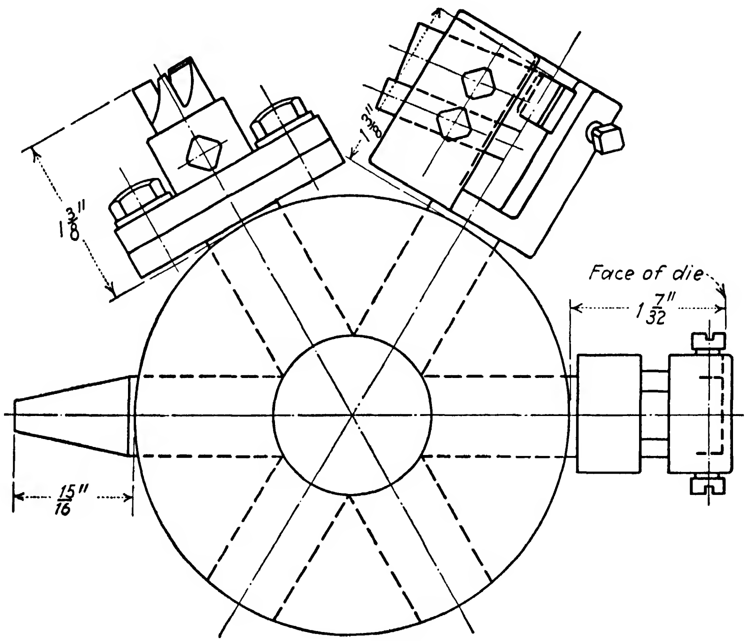


Fig. 20.—Tool layout for job.

deduct 0.060 in. to allow the die to draw away from the turret. The result, 0.490 in., is the rise for the lobe, and the drop for backing the die off of the screw must necessarily be the same.

When determining the height of the lobe, the amount of "pull out" allowed for the die must be taken into consideration.

The length of the die-holder head, as shown in Fig. 20, is $1\frac{7}{32}$ in. plus 0.060 in. allowed for "pull out." The result, which is approximately $1\frac{9}{32}$ in., is the total length of holder to be considered.

The threading begins at 48 hundredths and requires 15 hundredths of cam surface. The rise for following the die on the screw would be 0.467 in. ($7\frac{1}{2}$ hundredths). Locating the high point of the lobe at $55\frac{1}{2}$ hundredths, the length of the holder plus $\frac{1}{32}$ in. for clearance makes it necessary to cut the high point $\frac{15}{32}$ in. below the $4\frac{1}{2}$-in. circle.

Construct the increase curve for the drop and rise in the same manner as shown in Fig. 16 for the roughing cut.

The die will have backed off the screw at 63 hundredths and the portion of cam surface from this point to the starting point of the stop lobe should be cut down $1\frac{1}{8}$ in. from the $4\frac{1}{2}$-in. circle to allow the turret to remain in the rear position during the cutting off and facing operations. Allowance should be made for the drop from the point on the threading lobe and the rise for the stop lobe, using the templet, Fig. 18, for constructing the lines.

Cross-slide Cam Lobes.—The cross-slide cam blanks are $4\frac{1}{2}$ in. in diameter. It is not necessary to cut the high point of the lobes on the cams below this diameter when using forming and cutting-off tools, as the slides are arranged with suitable adjustment for producing any diameter within the capacity of the machine.

The rise and drop on the cross-slide cams are constructed from the templet (Figs. 17 and 18) and should be spaced in the same manner as the turret-slide cam, using the locating-pin hole for the zero line, in order to time the cams properly when placed in the machine.

The cutting off commences at 68 and is completed at 90 hundredths; the facing is from 68 to 78 hundredths.

Stock Stop, Spindle Reverse.—The stop lobe from 90 to 95 hundredths is without advance to produce a dwell of turret slide while feeding the stock. From 95 hundredths to zero, a drop necessary to bring the turret-slide lever roll $\frac{1}{16}$ in. below the starting point for the roughing cut is constructed.

The reversing of the spindle does not consume time enough to make it necessary to allow on the threading lobe for this change. The reversing of the spindle from backward to forward after cutting off can be carried on during the operation of feeding the stock or revolving the turret.

Cams for High-speed Machines.—In designing cams for the Brown and Sharpe high-speed machines, advantage is taken of

the faster production features. Consideration has to be given to the faster speeds, use of the swing stop, and double-indexing features, when they can be used to advantage.

The brass piece in Fig. 21 is made on the No. 00 automatic screw machine (high speed). Owing to the use of the swing-stock stop, no lobe is required on the cam for feeding stock.

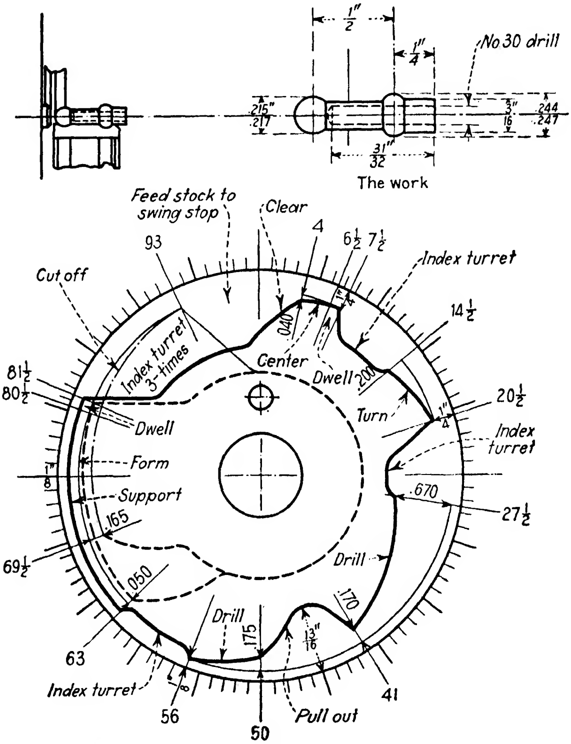


FIG. 21.—Work and cam layout No. 00 automatic.

On this machine ¼ sec. is required for feeding stock, which will be 21 spindle revolutions when the spindle is running 5000 r.p.m. This is increased to 24 by the allowance of a few revolutions for clearance. Similarly, indexing of turret which also requires ¼ sec., will need 24 spindle revolutions. A cam-design work sheet is shown in Fig. 22.

Cams for the No. 0 automatic screw machine (high speed) also are designed in this manner except that ⅓ sec. is required for indexing turret and feeding stock.

CAM DESIGN WORK SHEET

PART NAME OR NO...*Example* 1..............

MATERIAL....Brass......................
SURFACE FEET FOR STOCK................
" " THREAD...............
" " DRILL................
" " TURN.................
SPINDLE R.P.M. { FORWARD...5000........................
SPINDLE R.P.M. { BACKWARD..............................
SECONDS...4¼............................
GROSS PRODUCT PER HOUR...846.........
MADE ON..No. 00 H.S..................

Cut-Downs on Cams	Order of Operations	Throw	Feed	Spindle Revolutions: For Each Operation	Spindle Revolutions: After Deducting For Operations Overlapped	Spindle Revolutions: Readjusted to Equal Revolutions Obtainable with Regular Change Gears	Hundredths: For Spindle Revolutions in Preceding Column	Hundredths: For Operations that are Overlapped	Dwell
	Clear......					14	4		
	Center — No. 00A Floating Holder	.040	.005	8	8	12	3½		1
	Index Turret.....................				24	25	7		
	Turn — No. 00 Box Tool..........	.200	.0095	21	21	21	6		
	Index Turret.....................				24	25	7		
	Drill — No. 00A Floating Holder..	.500	.010	50	50	48	13½		
	Pull Out.........................					32	9		
	Drill............................	.170	.008	22	22	21	6		
	Index Turret.....................				24	25	7		
	Form — Front Slide and Support — No. 00A Floating Holder.....	.050	.0008	62	62	65	18½		1
	Cut Off — Back Slide............	.165	.002	83	41	41	11½		
	Feed Stock to Swing Stop.........				24	25	7		
	85 Hundredths Equal..............				300				
	Estimated Total Revs. if Spindle Runs 5000 R.P.M. Continually..				353				
	Nearest Actual Spindle Revs. Available on Machine...........					354	100		

Fig. 22.—Cam work sheet for piece Fig. 21, made on No. 00 high-speed automatic machines. (*Brown and Sharpe.*)

CHAPTER XIV

MULTIPLE-SPINDLE AUTOMATIC SCREW MACHINES

NATIONAL-ACME GRIDLEY MACHINE

The Gridley automatic screw machines built by the National Acme Company are in four-spindle and six-spindle types known as Model R machines. The four-spindle machines range in capacity from 7/8 to 2 1/4 in. and supplement the four-spindle Model GA automatic which is built in sizes from 2 5/8 to 3 1/2 in. The six-spindle machines are of 9/16-in., 1-in., 1 1/4-in. and 1 5/8-in. capacity. The four- and six-spindle machines are built on the same frames and are uniform in design so that an operator can run machines of both kinds in the same group without confusion. So far as possible, machine parts, tooling, and attachments have been made interchangeable to reduce tool costs. Collets and pushers for corresponding sizes of machines are also interchangeable.

The builders point out that to avoid in a large measure the most serious loss of time due to dull tools, or broken tools, and the work of removing and replacing them, the entire tooling section of the new machine can be opened up, so as to make each tool readily accessible for inspection or replacement. Furthermore, the tool is rigidly supported by heavier slides which in turn are rigidly supported by the bed casting of the machine, as rigid support is necessary for long tool life. These cross slides are supported on hardened-steel ways and are completely gibbed, so that the operator can readily compensate for wear. In the two upper positions they are inclined at an angle, as shown in Fig. 23, both to secure additional rigidity and to allow easier access to the tools.

High Spindle Speeds.—*To afford production speeds in accord* with modern cutting tools, very high spindle speeds are provided and the spindles are equipped with antifriction bearings.

All shafts are of large diameter and they are mounted on antifriction bearings. The gears are of alloy steel, heat-treated, and

all gears which operate at high speeds or are subject to heavy loads are of the helical type.

Productive capacity of the machine is due in part to the rapid and smooth indexing of the spindle carrier (Fig. 24) which is accomplished without shock. A modified Geneva mechanism

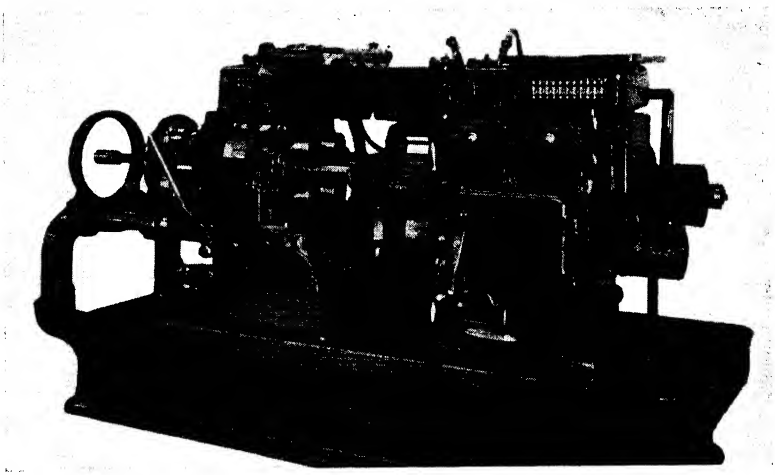


FIG. 23.—National-Acme Gridley automatic.

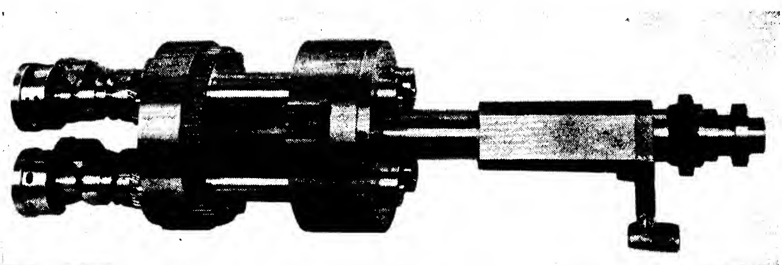


FIG. 24.—Spindle carrier of National-Acme Gridley.

starts the movement from standstill, indexes the spindle carrier rapidly and accurately into place, and brings it to a dead stop before the hardened locking pin slips into place. The roller on the indexing arm engages hardened-steel blocks on a gear which is constantly in mesh with a ring gear on the spindle carrier. This indexing mechanism reduces wear on the spindle-carrier parts, thus reducing materially idle time for machine repair.

The three-point bearing of the spindle-carrier design gives rigid support to this vital part of the machine. The two wide bearings of the carrier itself are supported in the spindle-carrier housing. The spindle-carrier stem, which is integral with the carrier and guides the main tool slide, is supported by an end bearing in the frame of the machine.

The machine is arranged to thread in the second or third position, or both, in all sizes, and the same slide and operating

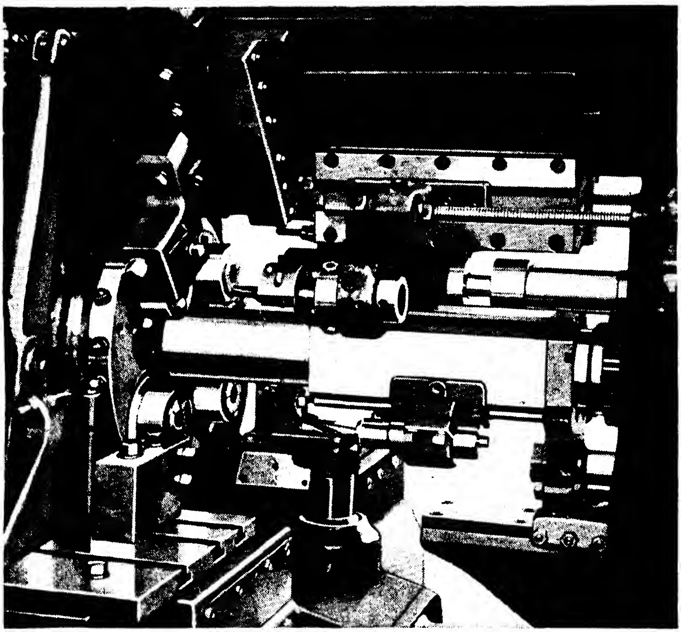


FIG. 25.—Typical set-up of tooling.

mechanism, in either position, can be used for accelerated reaming or turning operations. The slide in each position is operated by a separate cam, thus giving a selective feed in either position.

To employ both forming tools and drills at the correct relative surface speeds for each tool, high-speed drilling attachments can be used in all four positions—driven directly from the center gear mounted on the end of the spindle-carrier stem. Only one drive is required from the gear box to this center gear.

Figure 25 shows a typical set-up. It is clear that the operator can change tools or inspect and make adjustments

from either side of the machine. An improved disappearing stock stop (Fig. 26) makes possible the use of standard tooling in the fourth position and, for many jobs, this is the

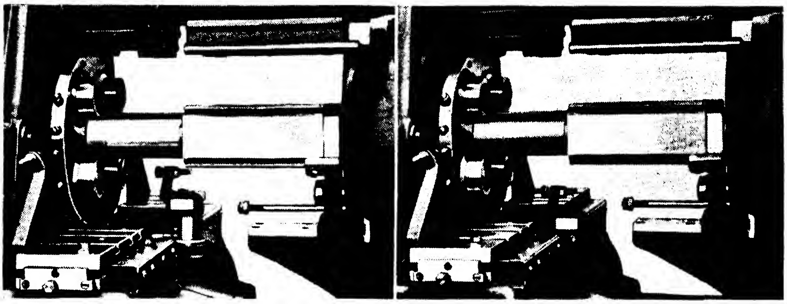


FIG. 26.—Stock stop in position and withdrawn.

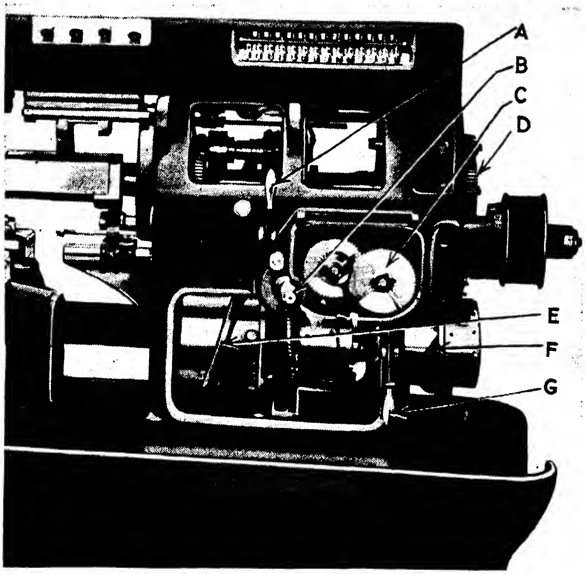


FIG. 27.—Construction of gear-box section. *A*, Start and stop lever. *B*, Shaft for hard crank. *C*, Feed change gears. *D*, Speed change gears. *E*, Main slide cams. *F*, Threading cams. *G*, High-speed lever.

equivalent of an additional work spindle. Attention has been given not only to accessibility of the tooling but to the easy replacement of any parts of the machine. The assembly is such

that the different mechanisms and parts are easy to get at and take apart. The cam drums, although mounted and guarded so that chips cannot clog this operation, are readily accessible, so that the operator can change cams with no loss of time. Heavy-barrel-type cams have been eliminated. Steel cams are used, wide-faced and strong, but easy to handle. The heavy tie piece on top of the machine securely anchors the gear-box section (Fig. 27) and spindle-carrier section into one rigid unit. This

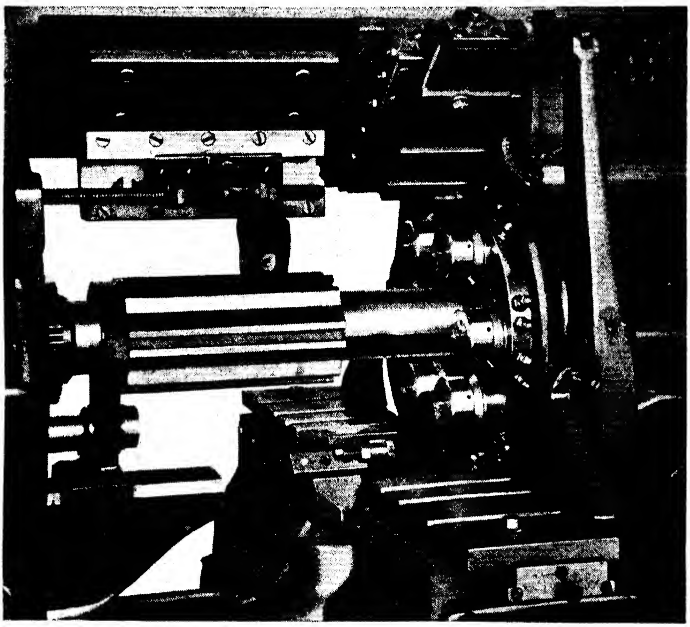


Fig. 28.—Spindle spacing in six-spindle machine.

design permits operation at unusually high speeds suitable for use with special tools such as tungsten or tantalum carbide. An unusually large space is provided for chips which rest on a steel plate for quick draining. They can be removed from either end of the pan while the machine is operating.

The lubrication of all bearings and working parts of the machine is taken care of by a pump which is located in the top section over the gear box and forces oil to the visible oilers; from these a separate copper tube runs to each bearing.

SIX-SPINDLE GRIDLEY MACHINE

Although of the same general design as the four-spindle type, the six-spindle machine has certain operative features which will be of interest. An important feature in the design of the six-spindle Model R is the arrangement or spacing of the spindles in the spindle carrier (see Figs. 28 and 29). The two spindles at the top and the two at the bottom are in line for direct application of tooling from the four heavy independently operated cross slides. The two spindles at the sides (second and fifth positions) are accessible for a "short-coupled" double-deck tool holder or an independent cross slide if required.

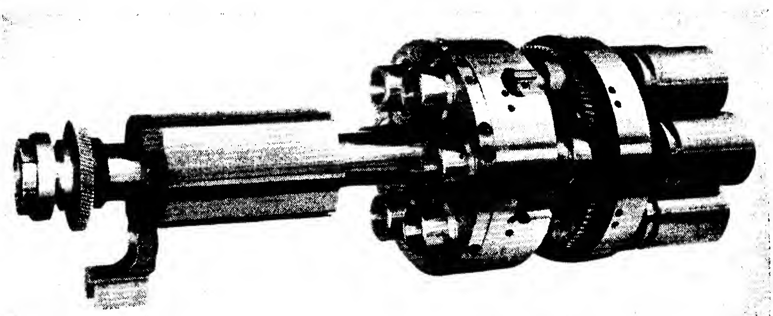


FIG. 29.—Six-spindle carrier head.

These machines are regularly provided with stock stop in the sixth position, but can be equipped with stock stop in the first position. The stop is brought into position by mechanism that is entirely enclosed. It drops quickly out of the way after stock feeds out and the collet closes, making possible the use of tooling in the feed position. This makes all six positions working positions and, in combination with the four independent cross slides, makes this six-spindle machine the equivalent of machines with a greater number of spindles.

A new design of finger holder operates the opening and closing of the collets. The fingers themselves slide on a hardened cam inside the outer steel shell. Both the fingers and the shell rotate with the spindle so that excessive wear on the fingers is eliminated. Centrifugal force does not effect the action of the fingers because they are enclosed within the steel shell. This is also a

safety feature because of the smooth exterior of the chuck finger mechanism.

The Spindle Carrier.—The spindle carrier, which is the heart of the machine, has large bearing surfaces which are clearly shown in Fig. 29. As in the four-spindle machine, it has a three-point support, and the unusually great length over spindle bearings affords great rigidity. High-speed drilling attachments can be used in any or in all six positions—driven directly from the center gear mounted on the end of the spindle-carrier stem. Only one drive is required from the gear box to this center gear.

The six-spindle Model R, is arranged to thread in the third or fourth position, or in both, in all sizes, and the same slide and operating mechanism, in either position, can be used for accelerated reaming or turning operations. These two die slides are independent of the main tool slide and of each other as they are each operated by a separate cam.

Another feature of these machines is the stock reel and method of indexing it. The front disk of the stock reel turns in a reel guide which is mounted directly on the end of the frame and pan. The stock reel is indexed by power through shaft and gear from spindle-carrier mechanism. This eliminates torsional strain and whipping action to the spindle carrier. The stock tubes are mounted in antifriction bearings so that they revolve with the bar stock.

The Chronolog.—The chronolog is supplied with these multiple-spindle machines. A glance at the register wheels through the glass windows, in the front of the instrument, keeps the operator or foreman informed as to the progress of any job. The chronolog also transcribes on a paper roll inside the case a complete printed tabulation for analysis and future reference of everything that has happened during the course of the production operation. This tabulation is called the chronorecord and shows the operator's number, and the time he starts and finishes a job; the reasons for idle time; accumulated minutes of idle time; accumulated minutes of productive time; and the number of pieces produced.

NEW BRITAIN-GRIDLEY AUTOMATIC

This is a four-spindle machine having a square tool slide centrally located between all the spindles, as shown in Fig. 30.

The spindles are controlled by cams, two cam layouts being shown in Figs. 31 and 32. These layouts show the whole 360

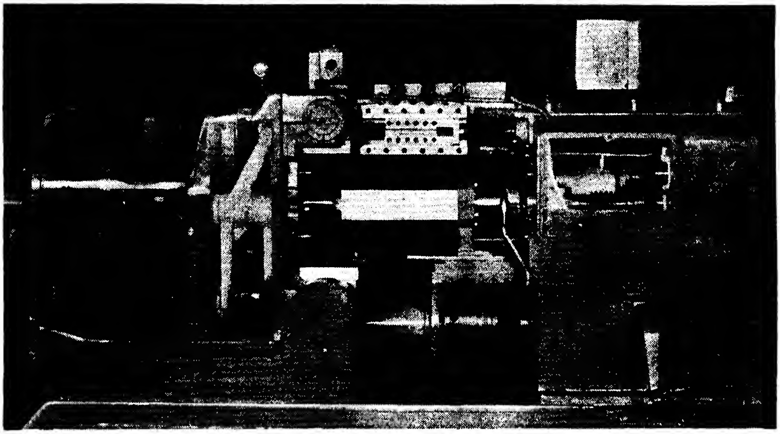


FIG. 30.—Four-spindle New Britain-Gridley automatic.

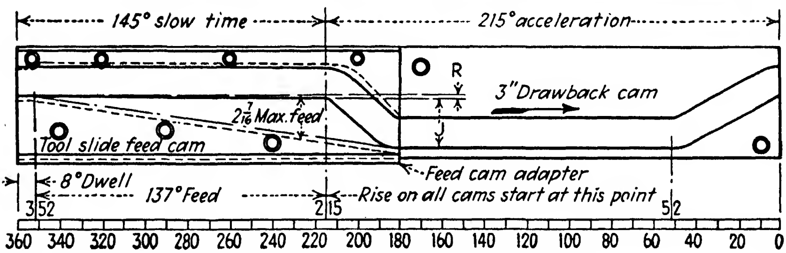


FIG. 31.—Cam layout for 3 in. cam.

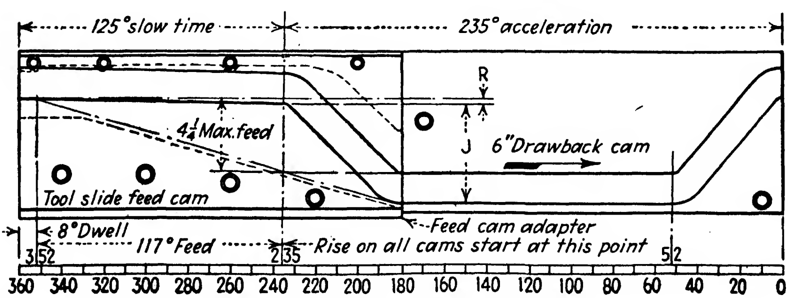


FIG. 32.—Cam layout for 6 in. cam.

deg. including the 8-deg. dwell, the slow and fast time, the portion through which the feed takes place, "rise," "jump,"

and "lead" varying by eighths of an inch, in both directions. These are given for both a 3-in. and a 6-in. throw.

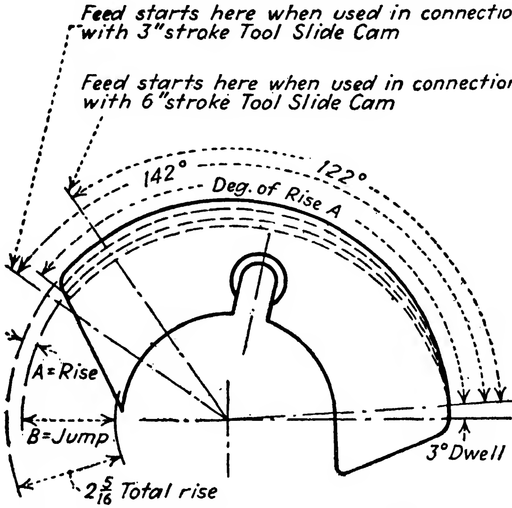


FIG. 33.—Forming slide cam for 3-degree dwell.

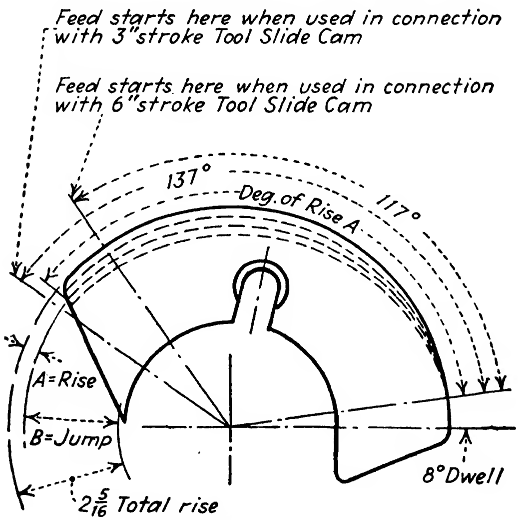


FIG. 34.—Forming slide for 8-degree dwell.

Figures 33 and 34 give the forming slide cams with both a 3- and an 8-deg. dwell. Both of these include the use of either the 3-in. or the 6-in. tool-slide cams. The tolerances on the

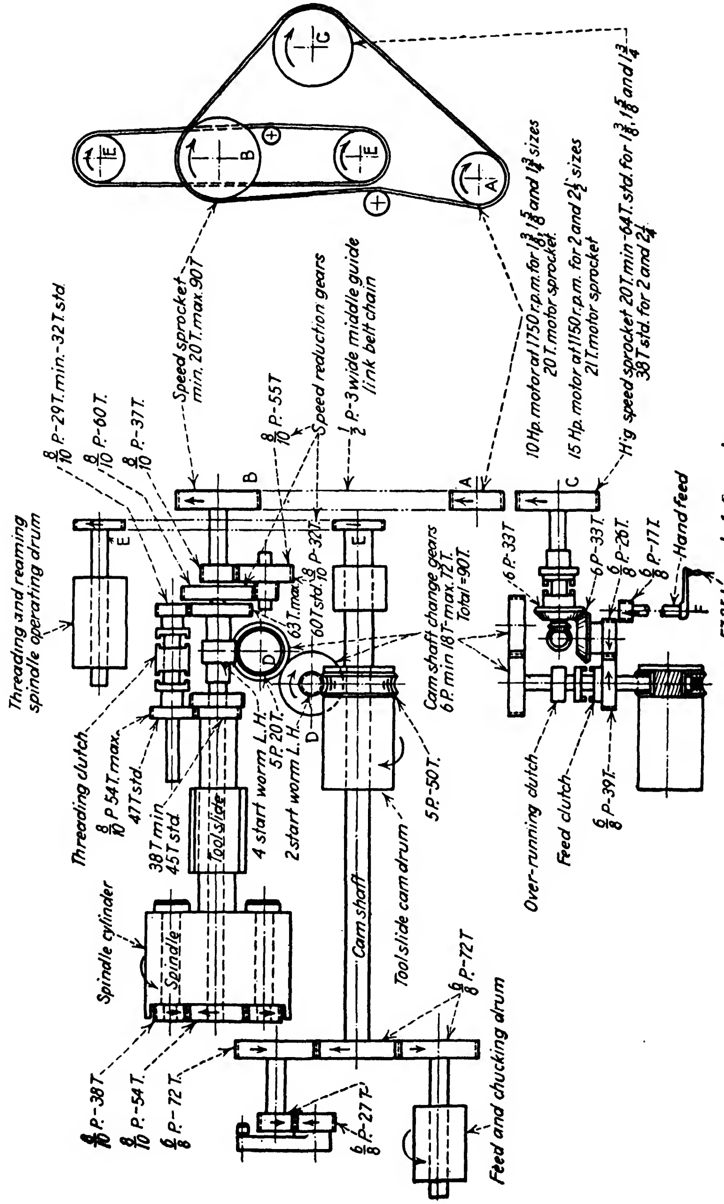


FIG. 35.—Gearing diagram for New Britain-Gridley automatic.

dimensions given are ± 0.01 in. where the dimensions are in fractions, and 0.003 in. where they are in decimals.

General Arrangement.—A general idea of the mechanism and its arrangement can be had by a study of Fig. 35 which is called the gearing diagram. Starting with the motor at A, either a 10 or 15 hp. according to the size of the machine, the power is transmitted by a 3-in. chain to B and C. Double-reduction worm gears at DD drive the camshaft, which in turn drives the threading and reaming spindle, a chain, and the sprockets EE. The hand crank for setting the cam drum is shown at F, this having a geared-down ratio of 57.35 to 1.

Table XIV gives spindle speeds with an 1,150 r.p.m. motor, showing the sprockets to use for the different speeds. This is for the larger motor which runs at 1,150, but the speeds for the smaller machine can be found by substituting 1,750 for the 1,150 and 20 for 21 in the formulas given at the bottom of the table.

Threading Speeds.—Effective threading spindle speeds for this machine are given in Table XV. This table is for straight speeds without reducing gears. These reduce the speed to a ratio of approximately 1 to 2.79. The constants at the bottom of the table give the effective threading speed for the different gear combinations. It will be noted that these include both "on" and "off" threading combination for both right- and left-hand threads. This is common practice in automatic-screw-machine work, where the cutting speed and the backing off depend on the *relative* speed of the tap or die and the work, as both frequently revolve.

The formulas at the bottom of Table XV give the necessary methods of figuring out the number of threads that can be cut, the lead of the threading cam, and the proper number of revolutions for the slow cam drum.

Production Chart.—A chart showing the production possible with this machine is given in Table XVII. This is a very complete guide for the man responsible for estimating machine production. It shows the maximum production per hour for different revolutions of the spindle, these varying with the length of the work. The feed advances are given below the main table, and the cam rises nceessary for the cross-slide travel at the bottom. All of these tables require study to obtain their full benefit.

TABLE XIV.—SPINDLE SPEED CHART FOR NO. 41 NEW BRITAIN AUTOMATIC BAR MACHINE (SPECIAL) MOTOR RUNNING 1150 R.P.M., WITH A 21T MOTOR SPROCKET

(36T high-speed sprocket – cam drum r.p.m. at high speed = 17.89 r.p.m. or 3.354 sec. per revolution)

(38T high-speed sprocket – cam drum r.p.m. at high speed = 16.94 r.p.m. or 3.54 sec. per revolution)

Main-drive sprocket	Spindle speeds	Spindle speed using reduction gears	Main-drive sprocket	Spindle speeds	Spindle speeds using reduction gears
20	1715	616	56	613	220
21	1635	586	57	603	216
22	1561	560	58	593	212
23	1493	535	59	582	209
24	1430	513	60	572	205
25	1373	492	61	563	202
26	1320	474	62	554	198.5
27	1272	456	63	545	195.5
28	1227	440	64	537	192.5
29	1184	425	65	528	189.5
30	1145	410	66	520	187
31	1109	397	67	512	184
32	1073	385	68	505	181
33	1041	373	69	498	178.5
34	1010	362	70	491	176
35	981	352	71	484	173.5
36	954	342	72	477	171
37	928	333	73	470	169
38	904	324	74	465	166.5
39	881	316	75	458	164.5
40	858	308	76	452	162
41	837	300	77	447	160
42	818	293	78	441	158
43	799	286	79	435	156
44	781	280	80	430	154
45	764	274	81	424	152
46	746	268	82	419	150
47	732	262	83	414	148.5
48	715	256	84	409	146.5
49	702	251	85	404	145
50	687	246	86	400	143.3
51	674	241	87	395	141.8
52	660	237	88	390	140
53	648	232	89	386	138.5
54	636	228	90	382	137
55	625	224			

$$1150 \times \frac{21}{\text{main-drive sprocket}} \times \frac{54}{38} = \text{spindle speed}$$

$$1150 \times \frac{21}{\text{main-drive sprocket}} \times \frac{37}{55} \times \frac{32}{60} \times \frac{54}{38} = \text{spindle speed using reduction gears}$$

TABLE XV.—EFFECTIVE THREADING SPINDLE SPEEDS FOR NO. 41 AUTOMATIC (1150 R.P.M. MOTOR, 21T MOTOR SPROCKET)

Main-drive sprocket	Work-spindle speed	Effective r.p.m. of threading spindle								
		R.H. threading on, L.H. threading off					R.H. threading off, L.H. threading on			
		Gears					Gears			
		38/54	40/52	43/49	45/47	47/45	63/29	62/30	61/31	60/32
20	1715	866	786	657	560	454	907	779	664	548
23	1493	754	684	572	487	396	790	678	578	477
26	1320	667	605	506	431	350	698	600	511	422
29	1184	598	543	453	386	314	626	538	458	378
32	1073	542	492	411	350	284	568	487	415	343
35	981	496	450	376	320	260	519	446	380	313
38	904	457	414	346	295	240	478	411	350	289
41	837	423	384	321	273	222	443	380	324	267
44	781	394	358	299	255	207	413	355	302	249
47	732	370	335	280	239	194	387	333	283	234
50	687	347	315	263	224	182	363	312	266	219
53	648	327	297	248	211	172	343	294	251	207
56	613	309	281	235	200	162	324	278	237	196
59	582	294	267	223	190	154	308	264	225	186
62	554	280	254	212	181	147	293	252	214	177
65	528	267	242	202	172	140	279	240	204	169
68	505	255	231	193	165	134	267	229	195	162
71	484	244	222	185	158	128	256	220	187	155
74	465	235	213	178	152	123	246	211	180	148
77	447	226	205	171	146	118	236	203	173	143
80	430	217	197	165	140	114	227	195	166	137
83	414	209	190	159	135	109	219	188	160	132
86	400	202	183	153	131	106	212	182	155	128
89	386	195	177	148	126	102	204	175	149	123
Work-spindle speed x→ = effective thread speed		0.505	0.4583	0.383	0.3263	0.265	0.529	0.4543	0.387	0.3194

$$\text{No. of threads that can be cut} = \frac{\text{no. of revs. to finish a piece}}{\text{work spindle, r.p.m.}} \times \text{effective r.p.m. of threading spindle in table}$$

$$\text{Lead of threading cam} = \frac{\text{effective threading-spindle speed}}{\text{slow cam drum, r.p.m.}} \times \text{lead of thread to be cut}$$

$$\text{Slow cam drum r.p.m.} = \frac{\text{work-spindle speed}}{\text{revs. to finish piece}} \times \frac{\text{deg. of feed}}{360}$$

TABLE XVI.—FORMULA FOR FIGURING PRODUCTIONS ON NO. 41 NEW BRITAIN-GRIDLEY AUTOMATIC SPEED-SPINDLE CHART TABLE XIV—GEARING CHART FIG. 35—1150 R.P.M., MOTOR, 21T MOTOR SPROCKET, 38T HIGH-SPEED SPROCKET

$$\text{Production per hour} = \frac{3600}{\text{total sec. per piece}}$$

Total sec. per piece = sec. of cam drum at slow speed + sec. at high speed

$$\text{Total sec. of drum} = \frac{\text{sec. per rev. of drum}}{360} \times \text{deg. at slow or high speed at high or slow speed}$$

$$\text{Sec. per rev. of drum} = \frac{60}{\text{cam drum r.p.m.}}$$

Cam drum r.p.m. using 1,150 r.p.m. motor, 21T sprocket and 38T high-speed sprocket

$$\text{Slow cam drum r.p.m.} = 1{,}150 \times \frac{21}{\text{speed sprocket}} \times \frac{\text{feed}}{\text{gears}} \times \frac{4}{20} \times \frac{2}{50} = \text{or}$$

$$\frac{193.2}{\text{speed sprocket}} \times \frac{\text{feed}}{\text{gears}} \times \text{r.p.m.}$$

Cam drum r.p.m. at high speed $= 1{,}150 \times {}^{21}\!/\!_{38} \times {}^{26}\!/\!_{39} \times {}^{2}\!/\!_{50} = 16.94$ r.p.m.

$$\frac{60}{16.94} = 3.54 \text{ sec. per rev. at high speed}$$

$$\frac{3.54}{360} \times 215 = 2.115 \text{ sec. (3-in. stroke cams)}$$

$$\frac{3.54}{360} \times 235 = 2.31 \text{ sec. (6-in. stroke cams)}$$

Cam drum r.p.m. using reduction gears

$$\text{Slow r.p.m.} = 1{,}150 \times \frac{21}{\text{speed sprocket}} \times \frac{37}{55} \times \frac{32}{60} \times \frac{\text{feed}}{\text{gears}} \times \frac{4}{20} \times \frac{2}{50} =$$

$$\text{or } \frac{69.317}{\text{speed sprocket}} \times \frac{\text{feed}}{\text{gears}} = \text{r.p.m.}$$

Cam drum r.p.m. at high speed = 16.94 r.p.m.

$$\text{Revs. to finish piece} = \frac{\text{spindle speed}}{\text{cam drum slow r.p.m.}} \times \frac{\text{deg. of feed}}{360}$$

$$\text{Spindle speed} = 1{,}150 \times \frac{21}{\text{speed sprocket}} \times \frac{54}{38} = \text{or } \frac{34{,}318.4}{\text{speed sprocket}}$$

Spindle speed using reduction gears

$$1{,}150 \times \frac{21}{\text{speed sprocket}} \times \frac{37}{55} \times \frac{32}{60} \times \frac{54}{38} = \text{or } \frac{12{,}313}{\text{speed sprocket}} = \text{speed with reduction gears}$$

A summary of the formulas necessary for calculating the production to be obtained from one of these machines (Table XVI), gives answers to the various questions that may arise.

Full directions accompany the machine, which is entirely electrically controlled. The machine will automatically stop

TABLE XVII.—MODEL 41 PRODUCTION CHART: USING 3-IN. TOOL-SLIDE CAM AND SPEED-REDUCTION GEARS

(Sizes 2 × 6 and 2¼ × 6)

Spindle r.p.m.	Spindle-speed sprocket	Revolutions of spindle required to finish piece																		
		270	222	186	158	135	117	101	88.8	77.3	67.6	59.2	52.5	45.2	39.5	33.8	29	24.6	20.6	16.9
		Camshaft change gears																		
		18–72	21–69	24–66	27–63	30–60	33–57	36–54	39–51	42–48	45–45	48–42	51–39	54–36	57–33	60–30	63–27	66–24	69–21	72–18
		Productions per hour (max. production at constant high speed is 1,017 per hour)																		
616	20	120	144	169	196	224	255	285	320	357	397	437	482	532	585	642	702	775	850	935
535	23	105	126	149	173	198	225	255	285	320	357	395	437	482	535	587	650	695	792	875
474	26	93	113	133	155	178	202	230	257	290	322	360	397	442	490	542	600	647	740	822
425	29	84	102	120	140	162	184	207	235	265	295	327	365	407	452	505	560	602	695	787
385	32	77	92	110	128	147	168	191	215	242	272	310	337	377	420	467	522	585	655	735
352	35	70	85	101	118	136	155	176	199	225	252	282	315	352	392	440	490	550	617	697
324	38	66	78	93	109	126	144	164	185	205	235	262	295	330	367	412	462	520	585	662
300	41	60	73	87	102	117	134	153	173	195	220	247	277	310	347	390	437	492	557	635
280	44	56	68	81	95	110	126	143	162	183	205	232	260	292	327	367	415	467	532	605
262	47	53	64	76	89	103	118	135	153	173	194	220	245	277	310	350	395	447	507	580
246	50	50	60	72	84	97	112	127	145	163	185	207	230	262	295	332	375	427	485	557
232	53	47	57	68	79	92	106	121	137	155	175	197	222	250	282	317	360	407	465	535
220	56	45	54	64	75	87	100	114	130	147	166	188	212	237	267	302	342	392	447	512
209	59	42	51	61	72	83	95	109	124	141	159	179	202	227	257	290	330	375	430	497
198	62	40	49	58	68	79	91	104	118	134	152	171	193	217	247	280	317	362	415	480
189	65	38	47	56	65	76	87	99	113	129	145	164	185	210	237	267	305	347	400	465
181	68	37	45	53	62	72	83	95	108	123	139	161	178	202	230	257	292	335	385	447
173	71	35	43	51	60	69	80	91	104	118	134	151	171	193	220	250	282	325	372	435

166	74	34	41	49	57	67	77	88	100	114	129	146	165	186	212	240	275	312	362	420
160	77	32	39	47	55	64	74	85	96	110	124	141	159	180	205	232	265	302	350	407
154	80	31	38	45	53	62	71	82	93	106	120	136	154	174	197	225	255	290	340	397
148	83	30	37	44	51	60	69	79	90	102	116	131	149	168	191	217	247	285	330	387
143	86	29	35	42	50	58	66	76	87	99	112	127	144	163	185	210	240	277	320	375
138	89	28	34	41	48	56	64	74	84	95	109	123	139	158	179	205	235	270	312	365
Feed advance per revolution of spindle with 1-in. cam																				
Tool slide		0.0037	0.0045	0.0054	0.0063	0.0074	0.0085	0.0099	0.0113	0.0129	0.0148	0.0169	0.0190	0.0221	0.0253	0.0296	0.0345	0.0406	0.0485	0.0592
Upper form. slides		0.0031	0.0037	0.0045	0.0052	0.0062	0.0071	0.0082	0.0094	0.0107	0.0123	0.0141	0.0158	0.0184	0.0210	0.0246	0.0287	0.0338	0.0404	0.0493
Lower form. slides		0.0023	0.0028	0.0033	0.0039	0.0046	0.0053	0.0061	0.0070	0.0080	0.0092	0.0105	0.0118	0.0137	0.0157	0.0184	0.0214	0.0252	0.0302	0.0368
Total rev. 145 deg.		286	235	197	167	143	124	107	94	81.9	71.6	62.7	55.6	47.8	41.8	35.8	30.7	26	21.8	17.9
Rev. 137 deg. (feed)		270	222	186	158	135	117	101	88.8	77.3	67.6	59.2	52.5	45.2	39.5	33.8	29	24.6	20.6	16.9
Rev. 8 deg. (dwell)		16	13	11	9	8	7	6	5.2	4.6	4	3.5	3.1	2.6	2.3	2	1.7	1.4	1.2	1
Cam rises with actual cross-slide travel																				
Cam rise		1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1	1 1/8	1 1/4	1 3/8
Lower slides 1 and 2		0.0396	0.079	0.1187	0.158	0.198	0.237	0.277	0.316	0.356	0.396	0.435	0.474	0.512	0.548	0.585	0.621	0.693	0.760	0.825
Upper slides 3 and 4		0.053	0.106	0.159	0.212	0.265	0.318	0.371	0.424	0.477	0.530	0.582	0.635	0.685	0.735	0.785	0.832	0.927	1.019	1.105

Production chart for New Britain four spindle No. 41 screw machine using spindle-speed reduction drive and quadruple-feed drive worm.
Motor running 1,150 r.p.m. 21T motor sprocket. 38T high-speed sprocket.
Tool-slide cam 2 7/16 max. feed 3-in. stroke—145 deg. slow time, 215 deg. acceleration. Accelerated speed is 16.94 r.p.m.
Seconds at high speed is 2.11.

feeding when any one of the four spindles runs out of stock. Interlocking switches prevent the motor from starting until the stock-feed slide is properly engaged for machine operation. A

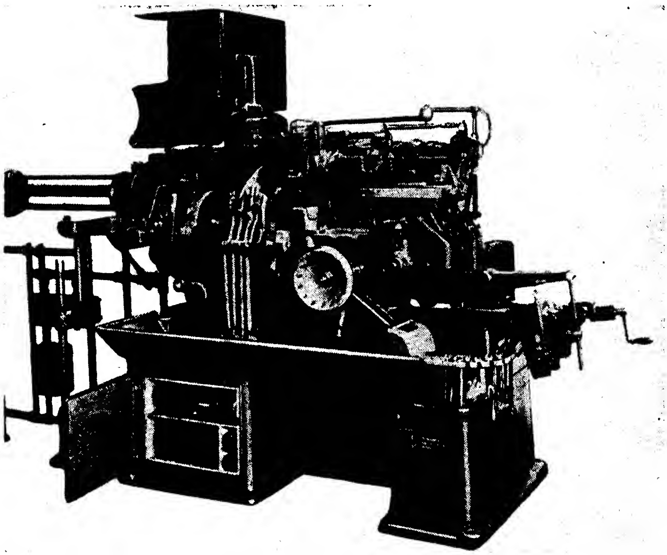


FIG. 36.—Davenport five-spindle automatic.

pilot lamp on the control box shows when current is flowing through the mechanism. The machine holds 16 gal. of lubricating oil and 85 gal. of cutting oil, which is circulated at the rate of 50 gal. per minute. The lubricating oil is circulated through a filter and oils all bearings, including spindles and slides.

DAVENPORT FIVE-SPINDLE AUTOMATIC

The new Davenport automatic screw machine is of five-spindle construction, built for high speed and precision, and recently redesigned to include improved features leading to even higher productivity and universal applicability to all classes of work within its range and capacity. A general view is shown in Fig. 36.

In its design are incorporated separate feed for each tool and adjustment for the length the tool must feed for finishing the work, to insure superior finish for the work and longer life for the tools. The set-up time and operating time have been reduced. The stock-feed length is changed with a crank. The noncutting time

of tools is reduced to ½ sec. The high-speed threading clutch is efficient on either brass or steel. A wide range of spindle speeds adapts the machine for the most efficient cutting speed for any class of work. There are five "turret" tools and four cross-slide tools, each having its own independent movement. A fifth cross slide can be added if required.

A clutch is provided between "turret" tool cams and cross slides. It is necessary to change only one gear when changing from one feed to another. The cams are mounted as a unit on a sleeve and the sleeve placed in position integrally. Another feature is the provision of extra sleeves that carry all cross-slide and "turret" cams for the next job. All levers for feeding and operating are at the front of the machine.

All operations are performed simultaneously and the actual time for a piece of work is the time of the longest operation plus ½ sec. Sometimes the longest operation can be cut into two or more short operations by doing the work on different spindles.

Work-spindle Head.—The work-spindle head is supported as at Fig. 37 on the outer end by a pair of rollers mounted on a bracket to take the overhang of the head and the weight of the wire-case carrier. The locating blocks are hardened and ground and the locating side is parallel with the radial line, the wear being taken on the opposite side, maintaining proper alignment. The work spindles are hardened, ground, and lapped and run in phosphor bronze bearings; the outside of the front box is tapered and adjustable for wear and the thrust is taken by a double-row ball bearing in the rear box. The spindle is driven by an internal gear running on the hubs of the spindle gears which are ground at the pitch diameter, making a perfect roller bearing. The head is indexed as shown, by a crank and Geneva disk which start and stop the head movement without shock. The Geneva disk is hardened and its slots are ground true after hardening. The stock feeding occurs while the head is indexing: The head is unlocked, the chuck opened, and the stock fed forward against the face of the first-position tool holder. The chuck is then closed, the head positively locked, and the feed tube again withdrawn ready for the next piece. Less than ½ sec. is required for these operations.

Stock-feed Cam.—The stock-feed cam also operates the chuck; it is a hardened unit, with the worm wheel and crank operating

the Geneva disk so that lost motion is eliminated between various movements. This unit is mounted on a short shaft at the front of the machine, together with the locating cam and cams operating the cross slides. The camshafts are operated at two different speeds, one half of the revolution being made in ½ sec.; the speed of the other half revolution is determined by the job.

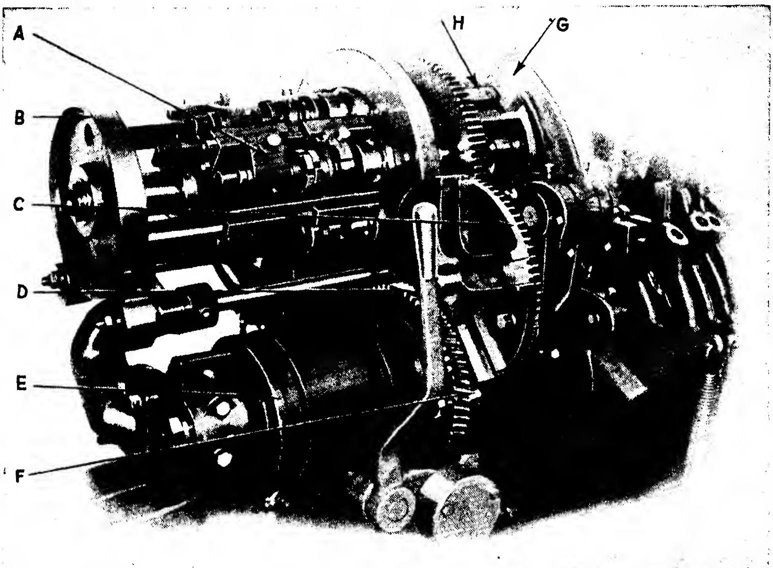


FIG. 37.—Davenport work-spindle head. *A*, Feed tube outer bearing. *B*, Outer support for revolving head. *C*, Geneva disk, hardened and ground slots. *D*, Worm wheel. *E*, Chuck and feed cam. *F*, Roller Geneva crank. *G*, Locating lever. *H*, Locating blocks.

The tool spindles (Fig. 38) are hardened and ground and slide in phosphor bronze boxes. The spindle levers have a graduated face where a sliding block (connected to the tool spindles by a turnbuckle) may be raised or lowered from the center line of the tool spindle to vary the feed of the tool as much as 20 per cent of the rise of the cam. The tool-spindle camshaft clutch disconnects that camshaft from the driving worm wheel so that the "turret" tools can remain in back position while the cross-slide tools operate as usual. This is a convenient feature while tooling up or feeding stock into the machine.

Four forming, cutting-off, or other cross-slide tools can be used. There are two regular cross slides in renewable seats attached to the bed, and two swinging arms. Circular forming and cutting-off tools are used. The tools are quickly adjusted for height of cutting edge and are adjustable longitudinally; there is also an eccentric for making a forming tool cut parallel or otherwise with the center of the work as desired.

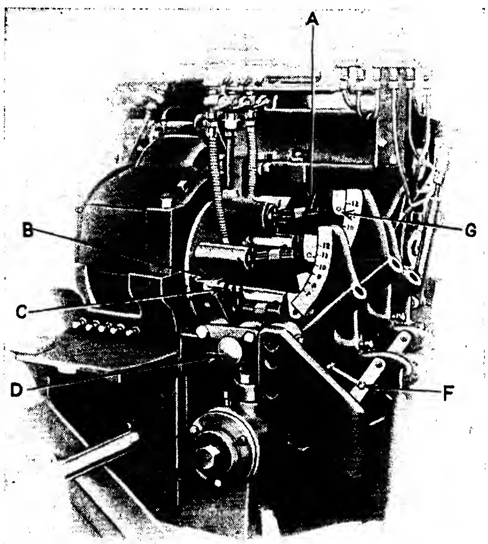


FIG. 38.—Davenport tool spindle head. *A*, Turnbuckle adjustment of tools. *B*, Stock-stop latch. *C*, Stock stop. *D*, Knob disconnects the cams from the worm wheel. *F*, Latch holds the levers away from the cams. *G*, Tool feed adjustment.

Two separate clutches operate the camshaft. The high-speed clutch—of the single-plate type—is at the rear of the machine. The low-speed clutch is in the feed-change-box integral with the driven feed gear. These change gears are at the right-hand end of the machine. When changing gears it is necessary only to change one gear as two compound gears on a swinging arm are easily moved into mesh.

Silent Chain Drive.—The silent chain drive is from a motor to a sprocket at the back of the machine. From this sprocket a shaft drives both the spindle and feed-change gears.

A large assortment of cams accompany the machine and two extra carriers so that cams can be changed on a carrier for another job while the machine is in operation.

The threading spindle with its clutch is equally efficient on brass or steel work. With an extra threading spindle it is possible to thread in more than one position at a time.

Attachments applicable to the machine include a chip conveyor, a screw-slotting attachment, rotary-slotting attachment, tool-spindle-slotting attachment, burring, and cross-drilling attachments.

The Model B machine shown has regular capacity of feed tubes for $\frac{1}{2}$-in. round, $\frac{7}{16}$-in. hexagon, and $\frac{3}{8}$-in. square stock. The longest feed is 3 in.; the longest length turned is $2\frac{1}{2}$ in. There are 11 changes of spindle speeds from 600 to 2,400 r.p.m. and 29 feed changes. The range of feed gears covers 1 to 20 sec. The tools used include box tools, die and tap holders, centering and facing tools, drill holders, recessing tools, knurling tools, swing tools, etc.

GREENLEE FOUR-SPINDLE MACHINE

The Greenlee four-spindle automatic screw machine combines novel features of design. For example, the feed of the tool slide is through intermittent gearing instead of by cam drums, and the shape of the slide is that of an inverted T in order to increase its capacity for tools. In addition there are four independently operated forming slides which are driven by plate cams—instead of drum cams—mounted on shafts running parallel with the bed. Other features are a three-piece collet-closing spool and stock-feeding rings, which do not rotate in the shoes; heat-treated alloy steel gearing throughout with all high-speed shafts carried in antifriction bearings; spindles mounted in double Timken bearings, and elimination of all parts which would not permit free access to tool and forming slides, thus making for easy set-up changes.

T-shaped Tool Slide.—The main tool slide of inverted T form is shown in the illustrations, Fig. 39 being a general view. Its operative intermittent gear is carried between the ways. This gear meshes with a rack on the underside of the slide to carry it forward. The return of the tool slide is by means of another set of teeth on the same gear, which meshes with another rack

suspended below the gear by a heavy arm from the bottom of the tool slide. There are five slots for tool holders. The tool slide travels the maximum distance at each cycle of the machine, but the feeding stroke is controlled by adjustable dogs carried on the face of the worm wheel. These dogs shift the feed clutch on the worm drive shaft.

Rotation of the intermittent gear is by means of worm and worm wheel carried on the side of the machine and driven by

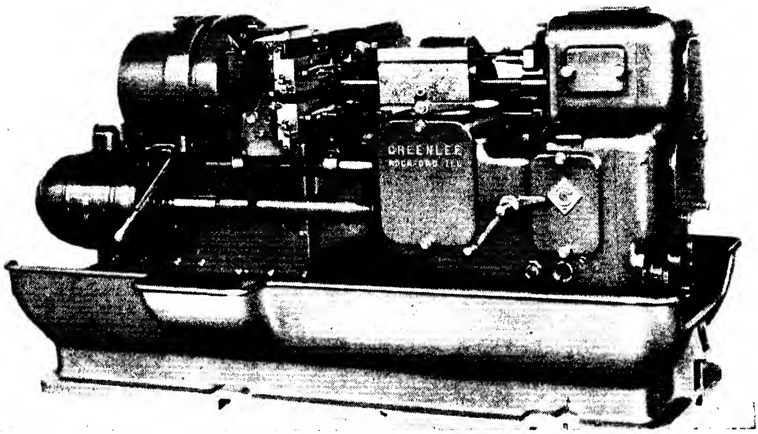


FIG. 39.—Greenlee four-spindle automatic.

high- and low-speed clutches from the speed box at the end of the machine.

The design of the tool slide provides for the use of tool holders with broad, flat clamping surfaces. They are attached to the side by T bolts and have tongues to fit the slots, making them very rigid.

The tool-slide arrangement makes possible the splitting up of long operations and the grouping of several in one position, thus reducing production time on many classes of work. Several tool holders can be mounted in any or all of the four positions, one behind the other, making possible such operations as turning, drilling, chamfering, knurling, etc., at each position. Chamfering, facing, and similar operations can be carried on from the top of the slide while the T slots on the sides are carrying tools for other operations.

High-speed drilling attachments can be used in any or all of the spindle positions. Threading and tapping can be done in

either or both the third and fourth positions. Attachments for accelerating, reaming, facing, hollow milling, etc., are provided when required.

Four Forming Slides.—The four heavy forming slides (Fig. 40) are carried in brackets attached to the spindle-carrier housing. Each slide has an individual cam for controlling forward and return movements, providing independent operation, so that heavy roughing cuts can be taken in the first and second positions and finishing cuts in the third and fourth. The forming-slide cams are mounted on two shafts under and parallel to the bed. Lever and gear segment transmit motion from each cam to the slide. Adjustable stops are provided to insure exactness in forming.

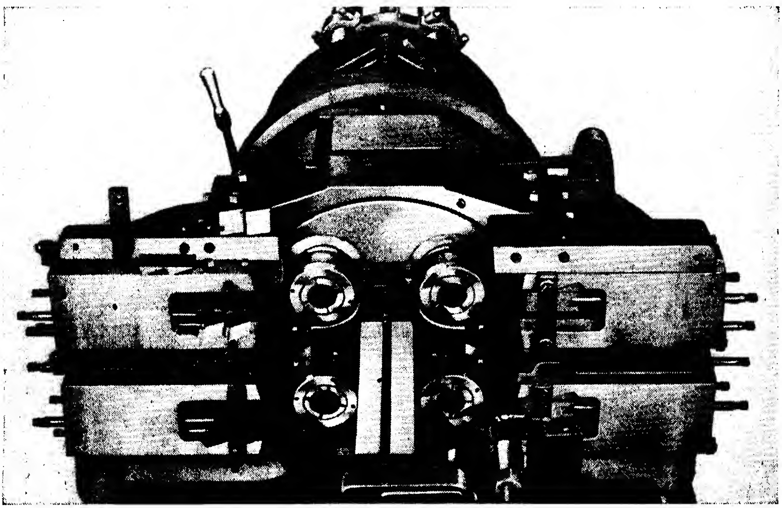


Fig. 40.—The four forming slides.

Solid, straight, circular, or dovetail tools of either the tongue or clamp type, knurling, shaving, skiving, or practically any desired special tool or holder can be held in any of the four forming slides.

The spindles are accurately ground inside and out. The spindle gears are of the helical type. The collets are stationary, eliminating facing operations to insure uniform lengths of work. The spindle carrier is a heavy, one-piece semisteel casting ground to size and with accurate spacing for the spindle secured by

precision operations in boring for the bearings. The indexing of the carrier is by a Geneva motion in connection with an offset double-index arm operated through internal gearing. This provides for fast, smooth index movement without shock, owing to the action of the roller on the indexing arm upon entering and leaving the Geneva slots. The spindle carrier is securely locked in position after indexing, by a large locking bolt of special design to assure permanent locking accuracy in bolt and spindle carrier.

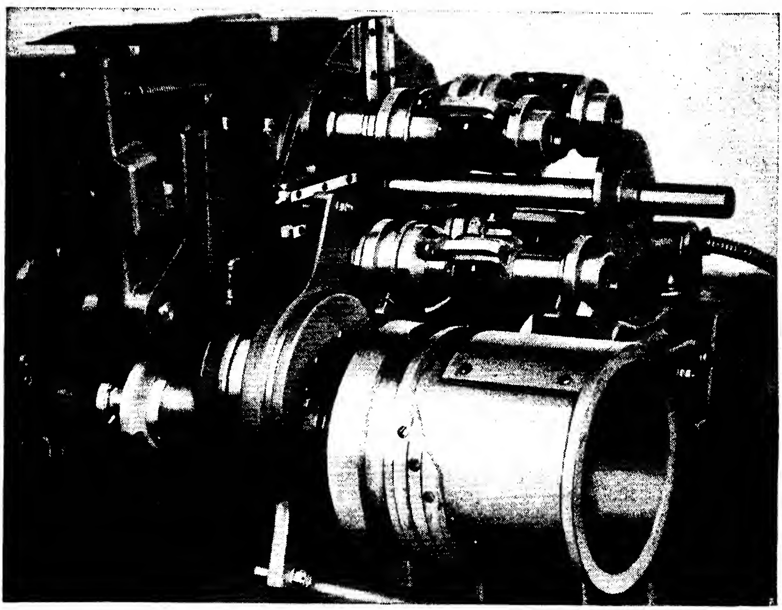


FIG. 41.—Collet and stock feeding mechanism.

Stock Feed.—The feeding of stock occurs between the fourth and first positions while the spindle carrier is indexing. The stock stop is carried in the tool slide directly under the spindle-drive shaft and is stationary at all times. Adjustment is made on the stock-stop rod, this arrangement making possible the use of end working tools in all four positions and also reducing the idle cycle since no extra time is required to move the stop in place and feed the stock before indexing.

Collet-operating and stock-feeding mechanisms are operated by cams mounted on a drum on the rear camshaft (Fig. 41).

Detachable strip cams determine the length of feeding movement. Each strip adds 3/4 in. to the length of the feed on the 7/8-in. machine, and 1 in. on all other sizes.

A hand lever for opening and closing the stock collets is attached to the machine and for safety purposes is automatically disengaged from the collet spool when not in use.

The gear box contains the spindle-speed and feed-change gears for the tool slides, also the high- and low-speed clutches and the safety clutch. The high- and low-speed clutch shaft

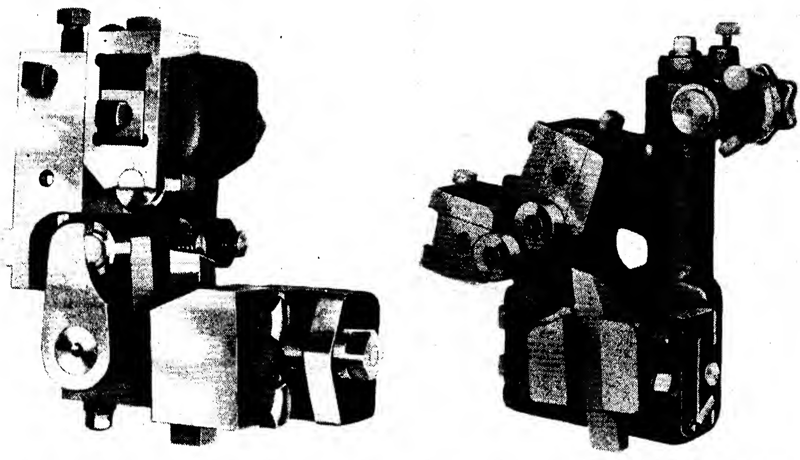


FIG. 42.—Two types of roller tools used on Greenlee machine.

for driving the tool-slide worm gear is mounted in two Timken bearings and one roller bearing. The safety clutch on this shaft throws out against spring pressure in case of overload, thus protecting against breakage and warning the operator.

Wide Feed Range.—Wide ranges of feed changes are available. These ranges are from 0.002 to 0.022 in. per revolution of spindle. The changes are made by pick-off gears, which are readily accessible by removing a small cover on the gear box. The feed is not affected when spindle speed changes are made.

Spindle speeds vary from a minimum of 147 r.p.m. in the larger sizes to a maximum of 4,000 r.p.m. in the 7/8-in. machine. A lever which is easily reached from either front or rear is provided for placing the machine in or out of feed.

Two typical roller back tools are shown in Fig. 42.

CHAPTER XV

COLLETS, CHUCKS, AND TOOLS

SPRING COLLETS AND FEED CHUCKS

Spring collets and feed chucks, or feed fingers, are the first tools to be considered in connection with screw-machine work, as upon these appliances devolve the operations of feeding the bar of material through the spindle and the holding of it while the different machining cuts are taken by the various cross-slide and turret tools.

When manufactured in quantities, the collet blanks are produced by the aid of forming tools and grinding for machining the exterior surface and by suitable internal tools of the drill and reamer order for finishing the interior to the required dimensions. In making a few collets at a time, however, as is generally the practice in the smaller shops, a few simple appliances suffice for the satisfactory handling of the work during the different operations.

Making Collets.—The collet blank may first be roughed out in the lathe and the inside chucked out and reamed taper from the rear end to leave the walls of the collet body of suitable proportions and to allow the collet to be slipped onto a taper-plug arbor, the rear end of which is fitted to the taper hole in the lathe spindle. While mounted on this arbor, the outer end of the collet is centered and center-reamed to allow it to be supported by the tail center. The body may then be turned and bored to correct shape and size without removing it from the arbor. It is sometimes advantageous to rough out two collets on the same piece of stock and then cut apart and mount on the taper-plug arbor for finishing separately. This method gives a longer and handier piece of material to work in the lathe.

The work is readily removed from the taper arbor on which it is turned, by means of a nut on a threaded portion of the arbor body adjacent to the taper section. Before taking the chuck

blank off from its arbor, the conical nose should be gaged carefully to make sure that it will fit properly in its seat in the screw-machine spindle. The hole, bored in the front end for the bar material, should be true and straight—especially if grinding is not to be resorted to after hardening. Of course, where absolute truth is essential in the running of the collet, it is important that the hole be ground after hardening with the collet seated in a grinder fixture in precisely the same way as it will later be operated in the screw machine.

Holding while Slitting.—The taper-plug arbor referred to can be used for carrying the work between the dividing head and tail center in the milling machine, while the slots are being cut to allow the collet to open and close on the material when in service. There are numerous methods of mounting collets for this slitting

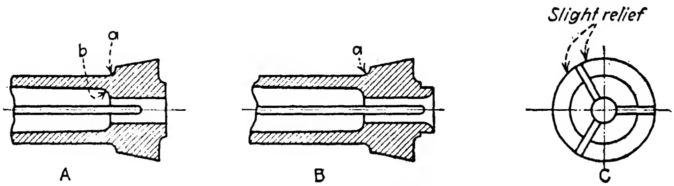


Fig. 43.—Method of making collets.

operation, but the one mentioned is as simple as any and entirely satisfactory where collets are put through in small lots and more elaborate fixtures are therefore uncalled for. If a small piece of flat stock is centered and introduced between the end of the work and the foot center of the dividing head, and the center itself flatted on top, sufficient clearance will be obtained for the slitting saw which is run into the work from the front end.

Collet Interior.—It is well to shape the interior of the collet about as illustrated in *A*, Fig. 43, the long curve or fillet *b* at the front end of the chamber where it joins the cylindrical hole, forming in conjunction with the fillet at *a* a strong section not likely to break away in the operation of the collet. The internal sloping surface at *b* also facilitates the passing of a fresh bar of stock into the collet upon the finishing up of the previous length of material.

Preparing for Hardening.—Before hardening collets it is common practice to open them somewhat to insure their having a given tension after hardening and tempering so that they will

open and release the stock the instant they are themselves freed by the cam-operated chucking mechanism. This opening of the collet must be carefully attended to or an eccentric and unsatisfactory job will be the result. Sometimes a simple fixture having a cone-pointed spindle is used for this purpose, the collet or chuck being held centrally while the cone plunger is forced between the chuck jaws sufficiently to open them evenly the necessary amount. However, no matter how much care is taken in this operation, the effect is lost unless the hardening is properly attended to, and the only sure way of producing a perfectly true collet with certainty is to grind it as a final operation.

Preventing Distortion.—Some toolmakers take the precaution of leaving a thin fin of metal at the front end of the collet in each saw slot, as at *A*, Fig. 43, in order that when hardened there shall be no chance of distortion due to unequal springing of the prongs or jaws. This metal tie or bridge at the ends of the jaws is readily removed by grinding out with a thin slitting wheel or lap. Still another scheme is illustrated at *B*, Fig. 43, which comprises in addition to the thin wall of metal at the front ends of the saw slots, a narrow ring or nose adapted to be carried on a grinder center while the collet is ground externally. Thus inequalities introduced in the hardening process may be rectified by grinding and afterward the superfluous metal at the end of the collet nose may be ground off, leaving the appliance ready for service.

Another method of preventing trouble in hardening collets is to insert a piece of sheet metal (say $\frac{1}{32}$ in. thicker than the slot width) in the front ends of the slots and then wire the nose of the chuck tightly so as to retain the steel pieces during the hardening operation. The collet must be heated uniformly and dipped so as to insure all three prongs being cooled simultaneously, otherwise they will be of different lengths and twisted, resulting in an untrue collet. With the best of care, a collet that is hardened, but not ground afterward, will generally require touching up on the conical portion of one or two of the prongs to insure its running true. It is not a difficult undertaking, however, to make a chuck run true within 0.002 in. by polishing one or two prongs.

In order that the collet may close parallel, it must be fairly long, and the exterior of each prong, or jaw, may be relieved by filing, as at *C*, Fig. 43, so as to insure its bearing along the center.

After hardening, the collet should be carefully tempered at the ends of the slots to prevent breaking at this point.

A Grinding Fixture for Collets.—A handy grinding appliance for spring collets is shown in Fig. 44, this sketch being made from a watch-factory device. This particular tool is adapted to receive an automatic screw-machine collet after it is hardened, and hold it during the grinding operation in precisely the same

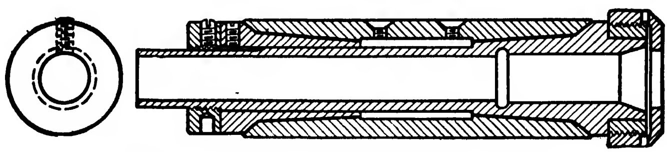


Fig. 44.—Fixture for grinding spring collets.

manner in which it will later be held in the screw machine when in operation. The quill in which the spindle is carried is slipped into a regular quill rest on the bench lathe or grinder, and the collet to be ground out is readily inserted and as easily removed when the grinding or lapping operation is completed.

All parts of this fixture, including quill, spindle, rear bearing, cone, cap, and adjusting nut, are of steel, hardened, ground, and lapped.

Feed Chucks.—The feed chucks or feed fingers need no such refinements in their production. They are usually closed after slitting on opposite sides, and thus after hardening they will maintain a constant grip upon the stock sufficient to feed the bar forward the moment it is released by the chuck. The idea is indicated in Fig. 45, which represents a typical feed chuck. Ordinarily the hole for the stock should be bored out a little over size, otherwise the corners of the feed chuck jaws when drawn back over the stock will mar the surface.

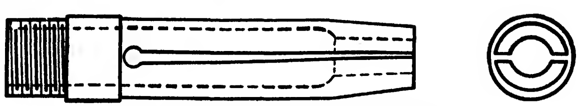


Fig. 45.—Fingers for feeding stock.

BOX TOOLS AND OTHER TURNING TOOLS FOR AUTOMATIC SCREW MACHINES

The hollow mill and the box tool are the commonly used turret tools for turning work in the automatic screw machine and also

in hand screw machines. Various types of box tools are made by different manufacturers of screw machines and the cutting tools or blades in these box tools are "tangent" or "radial" according to the purpose for which they are used. Ordinarily the tangent box tool is used, though the radial tool is employed on certain

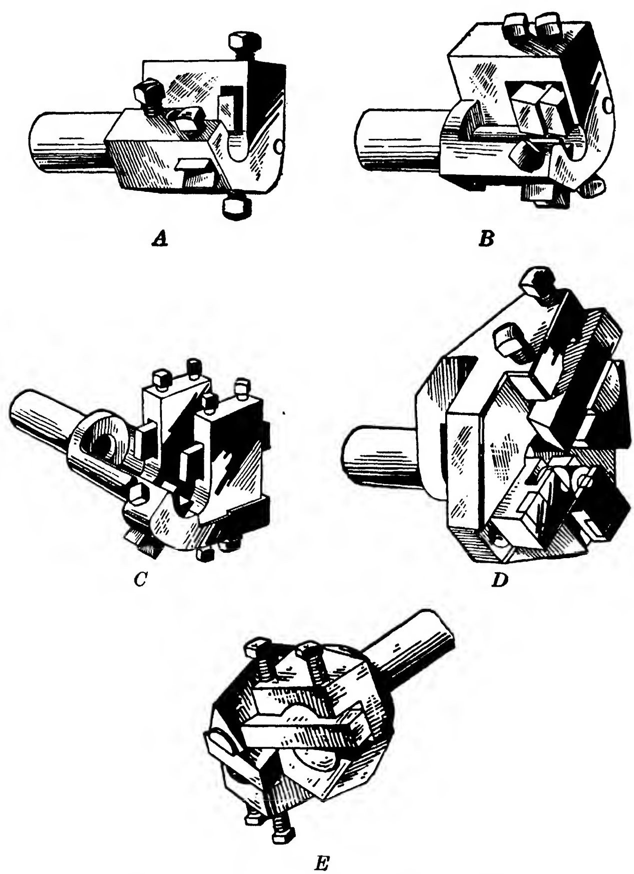


Fig. 46.—Five box tools of various designs.

finishing operations, and often for turning brass, also for end pointing and some other classes of cuts.

A group of box tools are shown in Fig. 46. These include hollow mills. Illustrations follow that show some of the more common applications.

The style of box tool in Fig. 46 at *A* and *B*, are for turning one or two diameters on general classes of work. The tool *B* can be used for a single diameter by pushing the cutter at the rear out of the way. The back rests are double ended, that is, beveled at both ends so that they can be used for both small and larger work. The cutters or blades are set tangent to the work, as in *C*, and adjustment is made with this tool by means of the screws shown. Such classes of tools may, however, be made with fixed position for work diameters, according to requirements.

A Brown and Sharpe roller back-rest box tool is shown in *D*, the blade being held in fixed position and the back rests adjustable. The rollers reduce friction, and the tool is intended for work requiring one cut only.

Another turret tool by the same makers is the balanced turning tool *E*. Such tools are designed for roughing only with one cutter or blade set to remove half the chip, the opposite blade set to the roughing size and ground slightly behind the other.

General Principles.—Practically all box tools consist primarily of a frame or body which is clamped to the turret of the screw machine. The box-tool body is utilized for holding the cutting tools and, usually, a work-supporting device commonly known as a back rest. In the frame there is also in some instances provision made for holding internal cutting tools such as drills, counterbores, etc.; in this latter case outside turning and boring may be accomplished simultaneously. The cutting tools are usually adjustable so as to be suitable for turning various diameters; the back rests or work-supporting devices are made both adjustable and solid or nonadjustable. Both cutting tools and back rests are preferably mounted in subholders permitting of longitudinal adjustment. The most common turning tools in use are for cylindrical work, but taper work can also be successfully produced by box tools designed for the purpose.

Conditions of Service.—The type of box tool in general, as well as such features as the work-supporting device and the manner in which the cutting-tool edge is presented to the work, are dependent upon various conditions, among which may be mentioned:

1. Length of work being turned.
2. Uniformity of diameter of stock used (bright drawn or rough stock).

3. Cross section of stock (circular or other).
4. Character of material.
5. Reduction in diameter to be made.
6. Character of longitudinal cut (cylindrical, taper, or other).

Types of Box Tools.—Figure 47 illustrates another form of box tool with movable blocks holding the cutters and with a back rest of the nonadjustable open type. The cutting edge of the tool is practically radial, but longitudinally the cutter lies tangent to the circle representing the work. This tool is used on hand machines especially. It is commonly called a roughing box and is for heavy cuts as there is less danger of springing, owing to the strain on the tool in cutting, than in the case of the radial tool in Fig. 48. The latter tool has movable blocks holding the cutters, and movable blocks carrying the back-rest jaws. Both cutters and back-rest jaws may be adjusted to suit different diameters of work. The cutting edge of the cutter is radial to the work and parallel with the longitudinal section of the cutter. The tool is used mostly for brass and similar material and for light cuts on steel. In this general form it is commonly known as a finishing box. On very free-cutting materials such as brass, the edge of the cutting tool is generally presented to the work without any rake. In cutting the harder materials, steel, etc., and especially in taking roughing cuts on such material, rake is desirable.

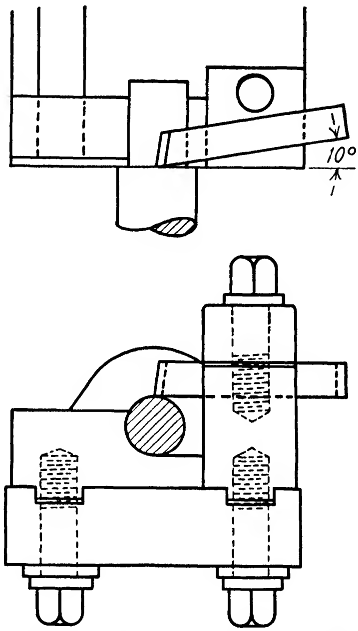


Fig. 47.—Tangent cutter and solid back rest.

The tangent cutter used in the box tool shown in Fig. 47 is sharpened by grinding on the end, and compensation for the grinding away of the metal is made by adjusting the cutter forward, whereas in the radial type of cutter in Fig. 48, frequent sharpening cannot be done without resulting in lowering the

cutting edge of the tool below the center of the work, unless a substantial part of the tool be sacrificed. The radial tool, however, is easily ground accurately on its face, which is the particular edge governing the finish.

Figure 49 outlines the general scheme of a box tool with tangent cutter having means of radial adjustment for various diameters, the back rests being adjustable also, as indicated.

Another box tool, used more on hand machines, has a back rest of the bushing type which fully envelops the work. A bush-

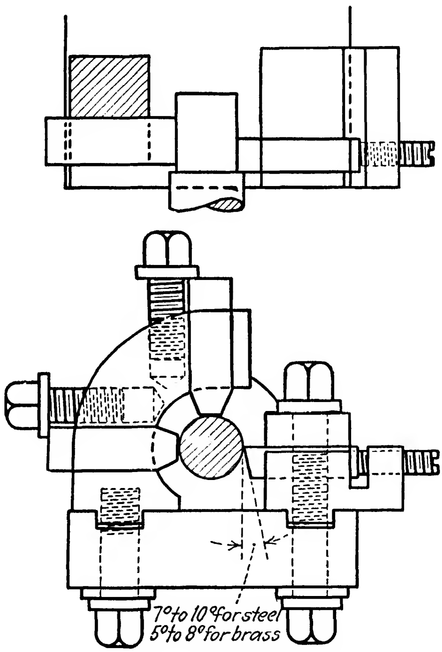


Fig. 48.—Radial box tool.

ing like that shown in Fig. 50 is frequently used in the bushing type of box tool. The bushing is tapered externally and drawn into a conical hole. It is thus suitable for slight variations in stock sizes. Figure 51 shows another "solid" rest, but without a bushing. The question of chip room frequently makes it necessary to abandon the bushing and bore the hole for the stock directly in the back rest. Quite often the back rest is cut away to allow the tools to operate on a second shoulder cut; then the bushing as ordinarily made interferes. As a rule, it is preferable

to use the bushing where possible, owing to the ease with which it may be replaced when worn out of shape, and also because of the facility with which any changes due to hardening may be corrected.

Other types of work-supporting devices, such as internal stem rests, are very commonly used. Figure 52 illustrates such a combination. Frequently, too, revolving stem rests are used in place of the stationary type shown. Quite often a drill or counterbore is held in the shank of the box tool in a similar manner and acts as a support, and also, as before stated, enables turning and boring operations to be accomplished simultaneously.

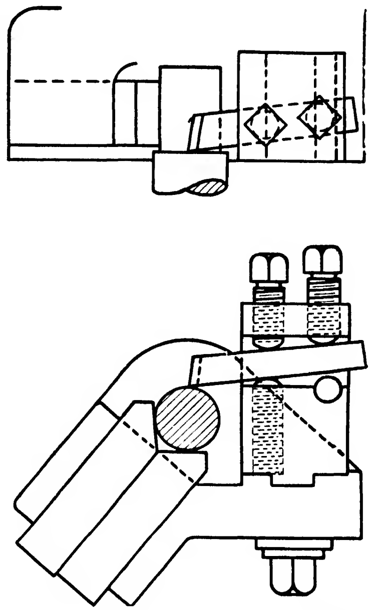


FIG. 49.—Adjustment for tangent cutter.

Selection of Back Rests.—Generally speaking, work that projects over one and one-half times its diameter from the spindle chuck cannot be turned accurately or rapidly without the aid of a support which will prevent the work springing away from its proper radial relation to the edge of the cutting tool.

Usually on work which does not project over five diameters from the chuck, the back rest is located so as to support the work by the diameter produced by the first cutting tool in the box tool, the back rest being set from about $\frac{1}{64}$ to $\frac{1}{32}$ in. back of the cutting tool. While any of the types of back rests shown may be used, on work of the length mentioned an enveloping back rest is not required. The type of back rest used in the tool in Fig. 46 at *A*, *B*, and *C*, is adjustable for wear and preferable on this account. The nonadjustable open back rests are recommended only when the design of the tool makes it difficult to utilize an adjustable type. All back rests should be of tool

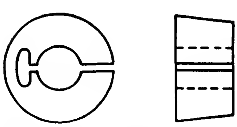


FIG. 50.—Taper bushing for adjustment.

steel. They should be very hard and smooth; otherwise when used on fast running material such as brass, a welding action

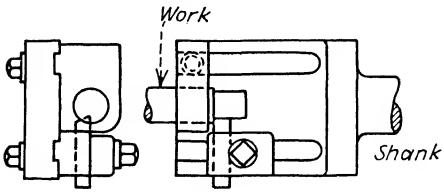


FIG. 51.—Box tool with solid-work support.

takes place. They should be ground and lapped on the bearing face so as to bear more strongly on the forward end of the work than at the rear. The clearance need not be more than 0.003 or 0.004 in. to the foot. Should the back rest be bell mouth, the work turned will be rough and covered with ridges.

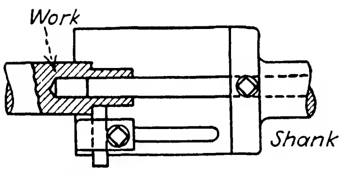


FIG. 52.—Center support for hollow work.

Tool Position and Lubrication.—Also it is quite important, where using such rests, that the work be not turned too large if roughing up of the surface is to be avoided. About 0.0005 in. freedom should be allowed for work up to 1/2 in. diameter, and about 0.001 in. freedom for 1 in. diameter. Proper lubrication of the bearing is also essential in preventing roughing up of the work. Lack of alignment of solid or half-open rests with the spindle of the machine may also cause the production of poor surfaces on the work, owing to the heavy crowding action under such conditions.

In setting adjustable back-rest jaws it will be found conducive to good work to hold a bar in the head spindle, turn a true running piece of work from 0.0004 to 0.0008 in. oversize and then adjust the jaws so that they will bear snugly on the turned part. The closer this is to the spindle the better. In using solid or nonadjustable open-back rests, it is recommended that they be bored out while held in the turret hole of the machine in which they are to be used. This insures the hole being in alignment

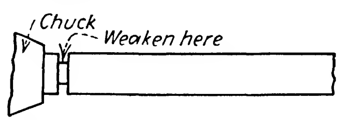


FIG. 53.—Weakening bar to secure true running.

with the head spindle; these conditions, as well as having the turret slide travel parallel with the axis of the head spindle, are necessary in order to produce accurate work.

Long and Short Work.—On very long work, when bright-drawn cylindrical stock of uniform diameter is being turned, the solid back rest is found satisfactory. The rest is in this event set ahead of the cutting tool and fully enveloping the work. It obviously prevents any tendency for the work to spring away. When heavy stock which does not run true is to be machined, it is necessary before turning, partly to cut off, as shown by Fig. 53, thus permitting the back rest to pull the bar into central position. In case there are short bends in the bar, trouble will be met, so that for long work machined in this manner it is necessary to select straight bars. It is also important where a back rest is used ahead of the cutting tool (that is, where the unmachined bar rotates directly in the back rest) to select practically uniform diameters of stock, not varying in size over 0.0004 to 0.0008 in. In some large screw factories bright-drawn stock is carefully gaged as soon as received and sorted out in this manner; in setting up the machine a back rest is selected to suit a particular bundle of gaged stock.

Irregularity of Stock Section.—Where stock is used which is slightly out of round, the use of a full-enveloping back rest preceding the cutting tool will give a two-point bearing, the pressure of the tool cannot force the work away, and the turned part will be cylindrical. With the jaw type of back rest the pressure of the cut will keep any irregular contour of the bar against a jaw. Consequently the jaws should follow the cutting tool. In such work, if the back-rest jaws are properly set, true work will result.

Cast-iron Work.—In machining cast iron (as on the magazine automatic), box tools with the ordinary types of rests are not satisfactory, owing to the fact that the cast-iron dust is apt to become ground between the rest jaws and the turned part of the work, thus causing the latter to become roughed up. The use of water, however (with just enough oil to prevent rusting), or any thin solution under pump pressure, effectually overcomes this trouble.

A box tool with roller back rests is excellent on cast-iron work when used in conjunction with an air blast to keep dust from accumulating between the rollers and work surface.

Hollow Mills.—Hollow mills are very suitable for turning long work from bar stock. These tools with multiple teeth support the work centrally, cut very rapidly and if held concentric with the head spindle and properly cleared will produce excellent results.

Figure 54 illustrates a form of hollow mill. The clamp collar shown in the group is commonly used for slightly adjusting the teeth to cut to correct diameter. Another good form of clamp ring is shown in Fig. 55. This is made with sufficient metal at one side to admit of clamping screw, while the opposite side of the ring is weak enough to allow it to close properly upon the mill when adjusted by the screw.

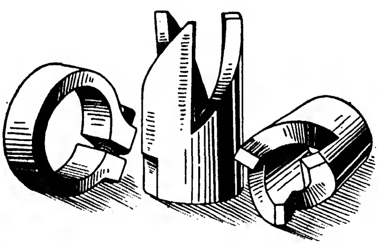


FIG. 54.—Hollow mills and clamping collar.

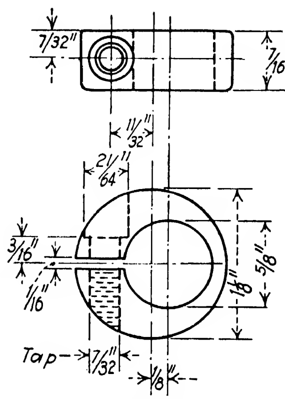


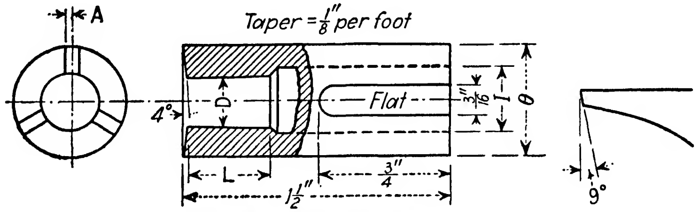
FIG. 55.—Round clamping collar.

The teeth of hollow mills should be radial or ahead of the center. With the cutting edge ahead of the center, as in Fig. 54, the chips as produced are caused to move outward away from the work and prevented from disfiguring it. With the cutting edge below the center, rough turning will result. With the cutting edge greatly above the center, chattering is produced. About one-tenth of the cutting diameter is found a good average amount to cut the teeth ahead of the center. When the chips produced from any turning or boring cut curl nicely, it is indicative of a free cutting action; but these chips are very troublesome on the automatic screw machine. In making hollow mills for the automatic, part or all of the rake to the cutting edge is generally sacrificed.

Hollow-mill Proportions.—The table under the hollow-mill sketch in Fig. 56 gives proportions of mills from $1/16$ to $3/4$

diameter, showing the amount to cut the teeth ahead of the center, the amount of taper in the hole, etc.

Besides the type of mill shown made in one piece, hollow mills are often used with inserted blades of high-speed steel. These tools are especially useful on the larger sizes of work.



D = Finishing	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	3/8	1/2	5/8	3/4
D = Roughing	.072	.104	.135	.166	.197	.229	.26	.291	.322	.385	.510	.635	.760
L =	1/4	1/4	5/16	5/16	3/8	3/8	7/16	7/16	1/2	5/8	3/4	7/8	1
A = $\frac{D}{10}$ =	.006	.009	.012	.015	.019	.022	.025	028	.031	.038	.050	.063	.075
I =	3/16	3/16	3/16	5/16	5/16	3/8	3/8	3/8	3/8	7/16	9/16	1 1/16	1 3/16
O =	3/8	3/8	3/8	5/8	5/8	5/8	5/8	5/8	5/8	1	1 1/4	1 3/8	1 5/8

FIG. 56.—Dimensions of hollow-mills.

Back-rest Construction.—In making back rests of the quarter-bearing type, as shown by Fig. 47, the usual custom is first to bore out the solid block from 0.005 to 0.001 in. over the size that is to be turned, and plane away the portion indicated at

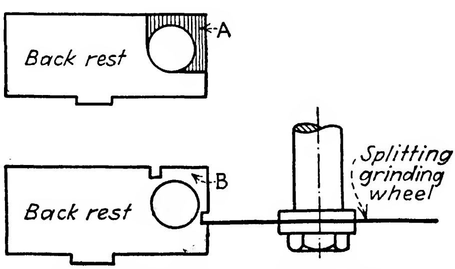


FIG. 57.—Making a solid back rest.

A, Fig. 57. The hole should be very smooth and cylindrical. Low-carbon tool steel is very good for the purpose, provided the work is pack-hardened; otherwise it is preferable to use high-carbon steel and harden in an open fire.

After the back rest has been hardened and assembled in the box-tool frame, the bearing may be slightly lapped with emery by holding a cylindrical piece of brass of correct diameter in the screw-machine chuck. The turret slide being moved back and forth will very quickly cause the lap to correct any slight crookedness due to the hardening.

When an exceptionally nice job is required, the back rest may be hardened after cutting in, as at *B*, Fig. 57; afterward, by using a slitting emery wheel, the corner may be removed entirely, leaving a little over the quarter bearing.

It is found good practice to give such back rests a width equal to one or one and one-half times the diameter of the work they are used on. It often happens, of course, that the positions of the cutting tools necessitate the employment of two rests in one box tool.

Box-tool Cutters.—It may be stated that present-day practice favors the use of high-carbon steel for the radial type of tools and high-speed steel for tangent cutters on heavy roughing cuts.

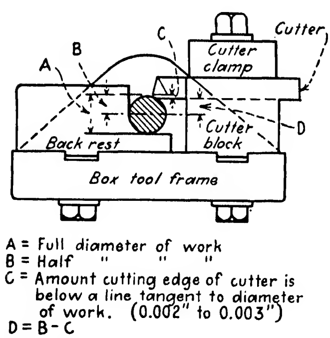


Fig. 58.—Diagram of tangent cutter.

Sections recommended for box-tool cutters are as follows: For box tools used for stock diameters up to 5/16 in., 3/16 in. square; up to 3/8 in. diameter, 7/32 in. square; up to 1/2 in. diameter, 1/4 in. square; up to 3/4 in. diameter, 5/16 in. square; up to 1 in. diameter, 3/8 in. square; up to 1 1/2 in. diameter, 1/2 in. square.

The "Tangent" Cutter.—While the box tool shown in Fig. 47 has been called the tangent tool, actually the cutter should not be exactly tangent to the diameter to be turned, as it is then impossible to adjust this type of cutting tool so as to cut under size, although by withdrawing the tool oversize work can be turned. In order to be able to compensate for slight errors and to insure that work may be turned to fit the nonadjustable back rest, it is the practice to plane the cutter block so that the cutting edge of the tool is about 0.002 to 0.003 in. below a line tangent to the diameter actually to be turned, as at *C*, Fig. 58.

The effect of in-and-out adjustment of the cutter is clearly shown by Fig. 59.

Operating Suggestions.—In order to facilitate the "starting on" of the box tool, it is well to have the end of the work beveled, as in Fig. 60. The forming tool in finishing the head of the

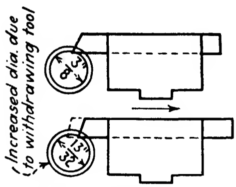


Fig. 59.—Tangent cutter adjustment.

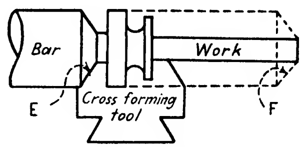


Fig. 60.—Pointing and forming work.

work simultaneously bevels a portion of the bar at *E* which, when a new piece of work is being produced, becomes *F*. The first cut of the box tool is thus made light and does not become heavy until after the support of the back rest has been secured.

Figure 61 illustrates an end-pointing tool used on the type of box tool just referred to. The form is planed in the end of the cutter as indicated, thus permitting frequent grinding without altering the form. Sometimes for pointing work a special pointing-box tool is employed, carrying merely a back rest and a pointing cutter; frequently a regular roughing-box tool is utilized and the pointing cutter is held in the hollow shank and prevented from moving by a set screw.

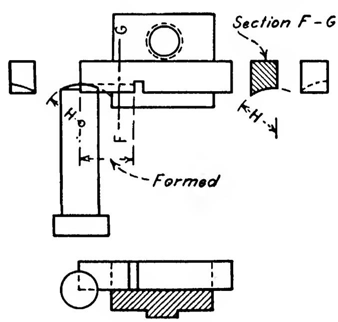


Fig. 61.—End-pointing tool.

DRILLS AND COUNTERBORES*

The design of internal cutting tools is largely governed by the character of the material to be cut, the depth of hole, and, in tools for finishing, the amount of material left by the roughing tool for removal.

* Some of the tools in this section, especially some of the larger sizes, are of particular interest in connection with hand-screw-machine and turret-lathe work.

As with external cutting tools the clearance and rake of the cutting edges, the number of cutting edges, and the means of avoiding accumulation of chips must be considered in connection with the nature of the material to be cut.

Starting Drills.—It is generally advisable before attempting to drill a long hole to use what is termed a starting drill, which tool is usually either of the flat type, as shown in Fig. 62, or somewhat similar to a twist drill, only having short flutes like Fig. 63. The point should be quite thin and the lip angles more acute than the drill that is to follow, as in this event the outer diameter of the drill is permitted to cut before its blunt noncutting center web comes in contact with the work. Figure 64 illustrates a twist drill entering a piece of work that has previously been spotted with a starting drill, and the twist drill will be found to run true under these conditions. When the blunt center web

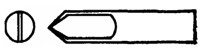


Fig. 62.—Flat starting drill.

Fig. 63.—Twist starting drill.

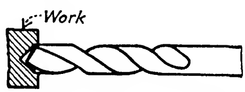


Fig. 64.—Best way of starting drills.

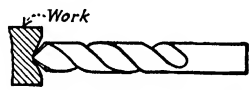


Fig. 65.—Not a good way.

of a drill is allowed to come in contact with the work first, as in Fig. 65, the value of the starting drill is not nearly so great as under the conditions in Fig. 64. For starting drills under 1/4 in. in diameter the flat starting tool, Fig. 62, is very satisfactory, while for larger work, except brass and similar materials, the type illustrated by Fig. 63 is more commonly used.

Spotting and Facing Tools.—On long, slender work made of smooth stock close to size and which projects some distance from the head spindle it is generally found necessary to support the end of the work close to the point being spotted, and in such cases the starting or spotting drill is held in a holder which is also suitable for guiding the outer end of the work. Figure 66 illustrates a tool of this type.

In some cases combination spotting and end-facing tools like Fig. 67 are used. This type of tool is very satisfactory on brass work, etc., but on harder materials, such as steel, which is more destructive to the cutting edges and thus makes frequent regrinding necessary, a tool holder having separate starting and facing

cutters, as shown in Fig. 68, is preferable, as the independent adjustments allow frequent sharpening to be more economically accomplished.

Twist and Straight-flute Drills.—In drilling cylindrical holes standard commercial tools are preferred owing to the convenience of replacement when they become worn out or broken. Ordinary twist drills are very satisfactory in steel and cast iron, although in very deep holes the chips are sometimes difficult to get rid of,

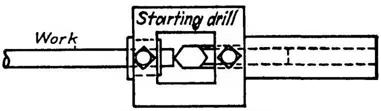


FIG. 66.—Guide for spotting small work.

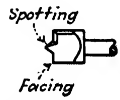


FIG. 67.—Combined spot and face tool.

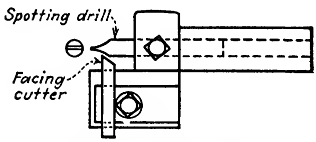


FIG. 68.—Separate facing cutter.

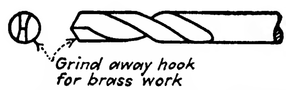


FIG. 69.—Hook of lip removed.

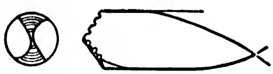


FIG. 70.—Serrated cutting edges.

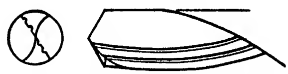


FIG. 71.—Extra flutes in drill.

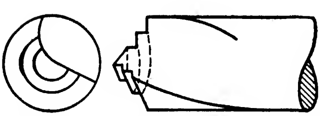


FIG. 72.—Single lip or gun drill.

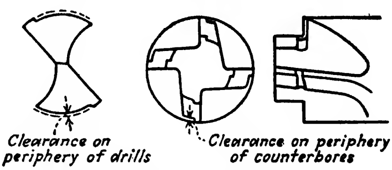


FIG. 73.—Clearance in drills and counterbores.

and clogging up of the flutes and occasional breakage will then occur unless frequent withdrawing of the drill is resorted to. On brass and all free cutting stock the rake given to the cutting edges of twist drills generally causes excessive curl to the chips and thus makes the automatic removal of the chips from the hole difficult. On automatic screw machines oftentimes a long curled chip is very objectionable as some machine functions may be interfered with. For these reasons, when twist drills are used in brass, it is good practice to reduce this rake by grinding in the lips at the front end, as in Fig. 69.

A two-lip, straight-fluted drill commonly known as a Farmer drill is generally superior to the twist drill in cases where the curling of the chips is troublesome, and in shops where brass work predominates, this drill is used much more commonly than the twist drill.

Serrated, Fluted, and Stepped Lips.—The cutting edges of drills are sometimes serrated as indicated in Fig. 70 to produce narrower chips than would otherwise result and facilitate their easy removal. A similar effect is produced by fluting the drill, as shown by Fig. 71. Still another method of producing narrow chips is to step the end of the drill. It may be of interest to mention that this latter scheme is very commonly used in the one-lip drills for drilling long holes in gun barrels, spindles, etc. Figure 72 will give an idea of this type of tool. When such a drill is carefully guided and advanced at a low rate of feed, it is possible to drill a distance of 30 or 40 in. with not more than 0.010 in. curvature in the length of the hole. There is no center web to prevent free cutting as in the two-lip twist drill, and oil is forced under pressure to keep the cutting cool and conduct away chips. The use of oil in this manner is found very effective with all classes of internal cutting tools, except when operating in cast iron. It makes possible the running of work at a high peripheral speed without excessive heat, results in rapid cutting, and insures long life to the cutting edges of the tool.

The center edge of all twist- and straight-flute drills should be thinned down at the cutting point, as the drill will then cut more freely and less power be required for the work.

Back and Land Clearances.—Drills should have some back clearance, from 0.007 to 0.015 in. per foot being common practice. The land back of the cutting edge should be quite narrow as little land is required to support the drill and prevent chattering, while an excessive width increases friction and heat, resulting in the welding of chips to the drill along these surfaces and the consequent production of rough holes of varying diameter. Fig. 73 represents the manner in which drills and counterbores should be cleared on their peripheries.

The milling cutters used to flute twist and other drills should be of such form as to produce a straight cutting edge on the drill. If there is a curve to the cutting edge, curved chips are produced which are difficult to bend or curl and such chips not only cause

excessive heat but put a severe strain on the cutting tool and cause frequent breakage of the latter.

The various steps on short internal cylindrical cutting tools should be tapered back about 0.020 in. per foot, and the peripheral contact reduced to a minimum so as to give ample chip clearance and avoid welding of chips.

Flat Drills and Counterbores.—Figure 74 illustrates a type of tool commonly termed a flat drill, which is extensively used on

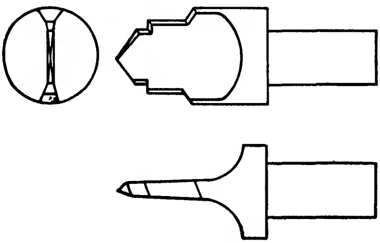


FIG. 74.—Flat drill for brass work.

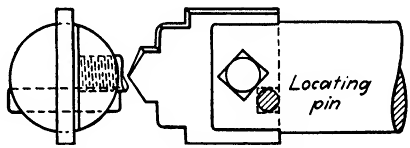


FIG. 75.—Holders for flat drill.

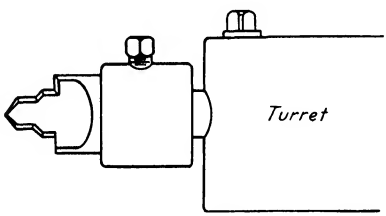


FIG. 76.—Flat drill mounted in the turret.

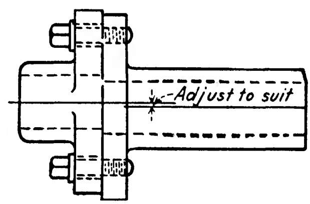


FIG. 77.—Adjustable holder.

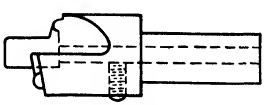


FIG. 78.—One-lip drill.

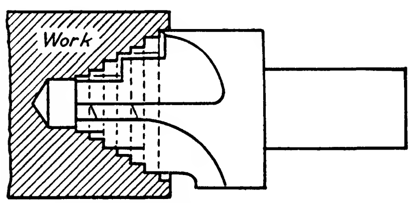


FIG. 79.—Stepped counterbore.

brass work; it is especially recommended for such material where there are numerous shoulders or forms to be cut out. The tool has a cylindrical shank which fits a turret tool holder. On large work it is customary to make the flat drill of rectangular stock and utilize a special holder, as shown in Fig. 75.

Such tools when held in the turret, as in Fig. 76, should be placed with the faces vertical so as to prevent them from cutting

appreciably oversize if the indexing of the turret, due to wear, is not perfect. In the event of the turret holder after long usage being badly out of line, an adjustable holder should be used. A tool of this character is illustrated in Fig. 77.

A one-lip drill or counterbore with a helical cut, as represented in Fig. 78, is found superior in many cases as it permits of grinding the cutting edge without changing the form of the hole produced.

Counterbores as well as drills should have sufficient back and peripheral clearance but should not have too many cutting lips. A back clearance of about 0.020 in. per foot is satisfactory. For counterbores up to 1 in. three flutes or cutting lips are ample; more flutes are apt to result in insufficient chip space.

Stepped Counterbores.—In making stepped counterbores where chips bother, it is conducive to good results to provide only one cutting edge for each step and to have successive cutting edges arranged spirally on adjacent cutting lips. Figure 79 illustrates a stepped counterbore for roughing a hole that is afterward to be finished by a taper reamer. The advantage of this stepped counterbore lies in its producing a hole with a number of slight steps without an undesirable quantity of chips to wedge and cause trouble. For brass work the flutes of counterbores should generally be parallel with the body of the tool, while on steel the flutes should be cut so as to give a positive rake angle of 10 to 15 deg.; the deeper the hole to be counterbored the less the angle of the tool. For steel, and particularly in deep holes, internally lubricated counterbores are effective in keeping the edges cool and in forcing out chips.

Machine Reamers.—Machine reamers are generally used for finishing holes smoothly and to size, and consequently it is advisable not to leave too much stock for these tools to remove. On steel work from 3/8 to 1 in. in diameter, from 0.004 to 0.008 in. is generally satisfactory, while in brass from 0.006 to 0.012 in. is a suitable amount. It is well to have the teeth of all reamers unevenly spaced, as there is then less liability of chattering than where even spacing is adopted.

Cylindrical reamers should cut only on the front end in entering the hole; they cut back of the front end, on the lips, only when the material being reamed alternately expands and contracts through undue pressure or variation in temperature produced

by the cutting action. This latter is particularly noticeable in brass tubing. Most cylindrical reaming tools like Fig. 80 are cleared the entire length of their cutting lips as well as having a back taper of about 0.004 in. per foot. For reaming steel where it is desired to produce an accurate smooth hole the so-termed rose reamer, Fig. 81, is excellent. This tool can cut only on the front end, and must be well lubricated and not forced

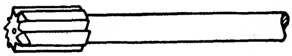


Fig. 80.—Machine reamer.

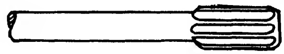


Fig. 81.—Rose reamer.

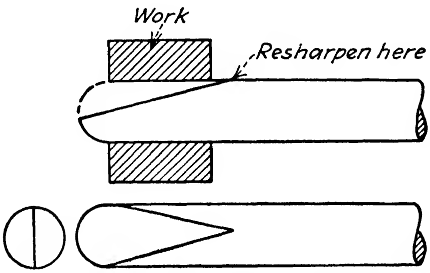


Fig. 82.—Flat reamer for brass.

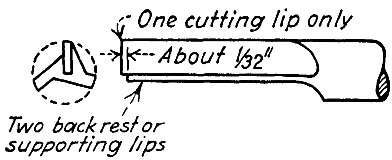


Fig. 83.—Special boring tool.

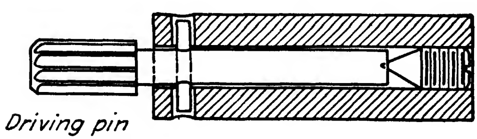


Fig. 84.—Floating reamer holder.

so as to expand the work. It will ream holes under these conditions that are satisfactory to the most exacting. For this work a rose reamer is better than a reamer with peripheral clearance, as its weight is more satisfactorily supported and there is thus more certainty of a round hole being reamed. A rose reamer, as intimated, has no peripheral clearance on the flutes, but should be back-tapered about 0.004 in. per foot.

The Cutting Edges.—The cutting edges of reamers are seldom undercut and are generally on center, although for brass it is considered by many advisable to mill the cutting edge ahead of center and so secure a scraping cut. The flutes are generally milled parallel with the body of the reamer, but in many cases a spiral-fluted reamer has been the means of obviating chattering.

The helix should be cut left-hand to prevent drawing in. In small work, particularly brass, a flat reamer like the one in Fig. 82 gives good results. It is inexpensive to make, and may be readily resharpened as indicated.

Reamers or, more correctly, boring tools with three flutes and with only one cutting edge, as shown by Fig. 83 are found very useful for producing straight, deep holes.

Reamer Holders.—Usually reamers for cylindrical holes (and sometimes finish counterboring tools) are carried in holders permitting of a floating action of the reamer. When a reamer is held rigidly in the turret hole it is apt to cut an oversize and tapering hole. There are a variety of floating reamer holders used. A simple form is illustrated in Fig. 84. With a reamer held in a suitable floating holder and provided the end of the hole that is to be reamed has been bored out so as to run true, and from 0.003 to 0.015 undersize, there should be produced a hole true to size and concentric.

Number of Flutes in Reamers.—The number of flutes cut in ordinary reamers should be as indicated in Table XVIII.

TABLE XVIII.—NUMBER OF FLUTES IN REAMERS

Hand	Chucking
1/8 to 7/32 diameter 4 flutes	1/8 to 7/16 diameter 6 flutes
1/4 to 15/32 diameter 6 flutes	1/2 to 1 1/4 diameter 8 flutes
1/2 to 1 1/4 diameter 8 flutes	1 5/16 to 1 11/16 diameter 10 flutes
1 9/32 to 1 23/32 diameter 10 flutes	1 3/4 to 2 3/16 diameter 12 flutes
1 3/4 to 2 7/32 diameter 12 flutes	2 1/4 to 2 3/4 diameter 14 flutes
2 1/4 to 2 3/4 diameter 14 flutes	2 3/16 to 3 diameter 16 flutes
2 25/32 to 3 diameter 16 flutes	

Taper Reamers.—Taper or formed reamers should be provided with clearance the entire length of their cutting lips. The lips or lands instead of being continuous are in the case of long reamers usually serrated by means of a narrow left-hand helical

groove, and this breaks up the chip into a number of curled strips instead of producing a single wide one. The flutes in taper reamers are sometimes milled left-hand so as to prevent pulling in, and sometimes right-hand to assist in cutting. On slight tapers any tendency to draw in must be obviated owing to the risk of breaking the tool, while on steep tapers which resist the feeding in of a tool an opposite effect is desired.

In practice, therefore, it is found satisfactory from the cutting point of view, to make the flutes left-hand in reamers producing holes tapering from 0 to about 1½ in. per foot. From 1½ to 2¼ in. taper per foot the flutes may be straight, while on tapers greater than this a right-hand flute is satisfactory. This latter gives a positive rake to the cutting edge, and less end pressure is required to force the tool to the cut than with straight or left-hand flutes.

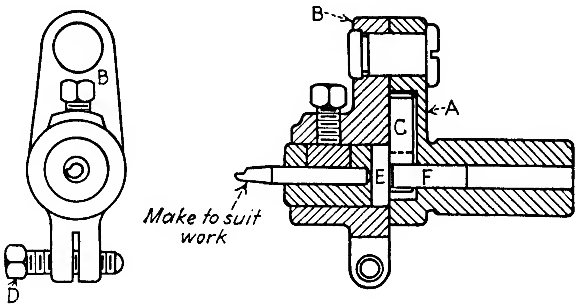


Fig. 85.—Recessing tool.

The cost of making tools with right- or left-hand flutes is somewhat greater than for straight flutes, and grinding is not so readily accomplished with ordinary equipment, hence straight-flute taper reamers are more commonly used.

Recessing Tools.—Recessing tools constitute still another class of internal cutting appliances used on screw-machine work for forming grooves and chambers in pieces after they have been drilled or bored out as required. There are many types of recessing appliances, one of which is illustrated in Fig. 85. The body *A* has a shank fitting the turret hole, and carries a stud upon which is pivoted the tool holder *B* in which is inserted the cutting tool. This swinging member *B* is held normally in central position by loop spring *C*. In operation, after the tool has entered the hole in the work to the required point

the cross slide advances and, acting upon adjusting screw *D*, presses the holder *B* toward the rear, causing the tool to cut the internal channel in the work. If a chamber or recess of some length is to be formed, the turret slide then advances and the tool takes a boring cut along the side of the hole. Upon completing its work, the tool is relieved by the cross slide receding, and is returned to central position by spring *C* which presses the pivoted tool holder *B* forward until a stop plug *E* contacts with stop pin *F* in the shank. The turret then withdraws the tool from the work.

CHAPTER XVI

SCREW-MACHINE TAPS AND DIES

The selection of steel for taps and dies and the manner in which the hardening is accomplished have a more important bearing on results than in the case of many other classes of cutting tools. This chapter is not intended to cover this phase

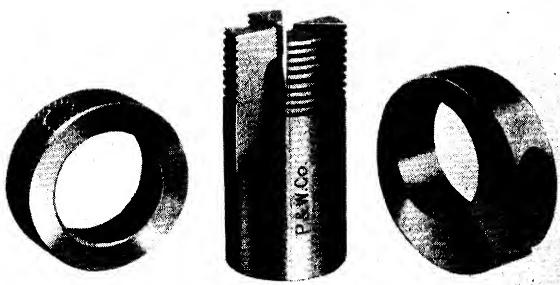


FIG. 86.—Spring threading dies.

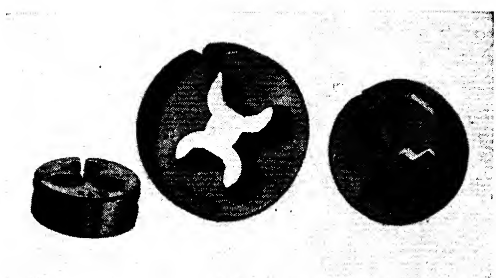


FIG. 87.—Button dies.

of the subject, but it may be opportune to state that in our experience it has been found best from an economical standpoint to temper a tap quite a little lower than a die. Exceedingly hard, brittle taps are liable to frequent breakage on account of their relatively weak cross section and small chip space as compared with a die.

Keeping taps sharp is more economical than continually making new ones to replace those breaking on account of being unduly hard. A die, however, may be designed to have ample metal for strength and much more chip room than the tap. Consequently breakage from this cause is not so liable to occur as with the tap. Furthermore, regrinding of a die is considered more difficult than regrinding a tap, and therefore the die is generally left harder than the tap. The speed of work while external threading operations are performed may be higher than for internal threading on account of the foregoing reasons and also because of greater facility for properly lubricating. Tables of speeds for dies and suggestions on lubricating are given in Chap. XII.

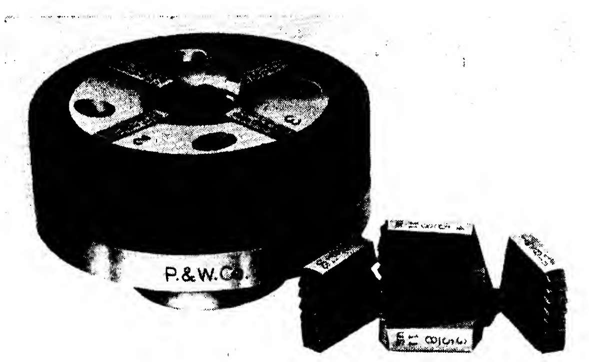


FIG. 88.—Die with inserted chasers.

Types of Dies and Taps.—Figure 86 represents what is commonly known as a spring screw-threading die, with its clamping or size adjusting ring, and Fig. 87 a button die. Both of these tools are used extensively in the automatic screw machine. On large work dies with inserted chasers, one form of which is shown in Fig. 88, are found very satisfactory. Various types of opening dies are also being successfully used on different classes of work.

Taps are generally made solid, although there is doubtless economy in the inserted blade type of tap when of large dimensions. Collapsing taps are also made for some lines of work.

Spring Dies.—Owing to the movable parts which may affect perfect alignment between the turret hole and the head spindle of

turret machines, it is found impracticable to hold dies or taps, even if perfectly true and concentric, directly in a turret hole or in a rigid nonadjusting tool holder. Ordinary commercial spring screw-threading dies, even when mounted in holders permitting of side play, are apt to produce better results if made with three cutting edges, as in Fig. 89, than if provided with four or more cutting edges. With the latter, the result due to changes in hardening or imperfect workmanship is apt to be that only two diametrically opposite teeth are simultaneously cutting, as shown in Fig. 90. This causes the die to vibrate and produce

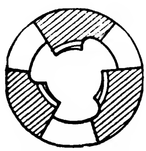


FIG. 89.—Die with three cutting prongs.

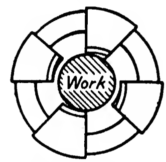


FIG. 90.—Four prongs spring in hardening.

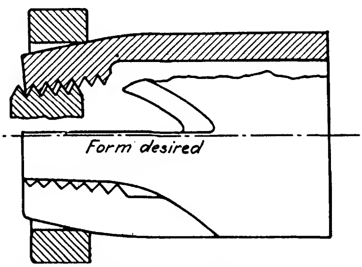


FIG. 91.—Prongs forced in too much.

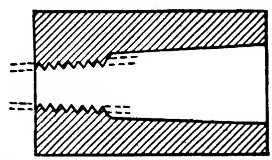


FIG. 92.—Die threaded correctly.

a rough thread, with chatter marks. With commercial dies having three cutting edges and providing that they are mounted in a free holder, these troubles are greatly reduced.

Tapping out the Die.—It is good practice in making spring-screw dies to either hob out the thread with a hob tap 0.005 to 0.015 in. oversize, according to size, and in use to spring the prongs to proper cutting size by a clamping ring as shown in Fig. 86, or to tap the die out from the rear with a hob tap tapering from $\frac{3}{16}$ to $\frac{1}{4}$ in. per foot, leaving the front end about 0.002 in. over cutting size, and in this case also to use a clamping ring. Both of these schemes are for the purpose of obtaining back clearance and are effective. Theoretically, the use of the taper hob is the best, and is to be preferred especially

when work is to be cut with threads of included angle less than 40 deg., as the shape of thread produced by clamping the prongs of the die to a size below that at which it is hobbed may then be effective enough to be decidedly unsatisfactory. Figure 91 illustrates this bad feature.

Figure 92 illustrates the die with the taper somewhat exaggerated, as made with a taper hob and the general internal form of a very satisfactory spring screw-threading die.

Hardening.—In hardening a die it frequently happens that curves to the lips are produced as in Fig. 93. When clamping the prongs of an oversized hobbed die (with such curvature)

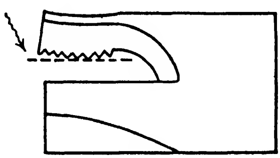


Fig. 93.—Prong spring in hardening.

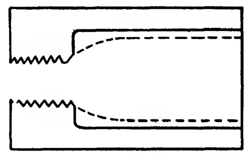


Fig. 94.—Prongs correct.

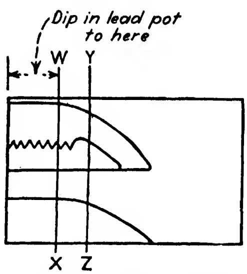


Fig. 95.—Suggestion for hardening.

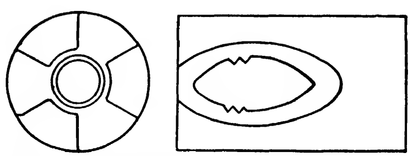


Fig. 96.—Tie left to prevent springing.

down to size, this will still result in a bell-mouth die. With a die hobbed out with a tap of sufficient back taper, as in Fig. 92, the curve, if it exists, will not result in a bell mouth; the clearance angle, being more pronounced than with an oversize tapped die, neutralizes the curvature. The internal form shown by full lines in Fig. 94 is bad, as the thickness of metal varies so that in hardening trouble will result. In Fig. 89, and as shown by dotted lines in Fig. 92, is a more satisfactory internal form.

Probably the best practice in hardening is to dip the prongs into the lead pot not further than the line *W-X*, Fig. 95, in which case less trouble will result, and the heat will still be

sufficient to cause the remaining portion of the prongs to be sufficiently hard when chilled, to prevent welding of chips, etc.

In case the hardening effect extends back into the curve as at *Y-Z*, side-twisting of the prongs is almost a certainty, and the cutting edge of the die in this event will not be in contact with the work, but a portion back of the cutting edges will be dragging on the work which will cause a ragged thread and oftentimes break off the piece being threaded.

In spite of care there is much risk in the *length* of the prongs being at variance after hardening, and it is conducive to good results to leave a tie to the prongs as shown in Fig. 96. This tie can be removed in two or three minutes by the use of a slitting grinding wheel.

With a three-prong die it is possible to provide lips of generous cross section, giving rigidity. The undesirable friction due to too much thread in contact with the work is overcome by milling out as in Fig. 89, to suit the material being threaded.

Cutting Edges.—The cutting edge of a spring-screw die is generally radial for brass, and it is permissible for the edge to point a trifle below center, particularly when there is any possibility (owing to the ease of cutting) of there being a strong chip produced which may cause a "hogging-in" action. On steel or material not free cutting, and which opposes the cutting action, it is desirable to have a positive rake to the cutting edge so as to make the cutting action easier, hence the cutting edge is generally above center. The amount is limited only by the chip curling so as to be objectionable on account of clogging, or by the rake being so much as to cause too free cutting, and consequently the production of a big, strong chip and the "hogging-in" action which in this event, owing to the cutting edge being above center, produces very bad results.

It should be observed that where large diameters of brass are to be threaded and where the die is so rigid that no springing action can take place, the radial-cutting edge is not so desirable as where there is positive rake to the edge.

Chattering, etc., on large work is generally due to weakness of tool or tool holder, and increased rigidity in these oftentimes makes possible an increase of clearance and particularly an increased positive rake to the cutting lip angles of all tools, with the result of better cutting action.

It is desirable in spring-screw dies to make the outside true with the axis of the thread and cutting edges, and consequently it is found desirable to grind the outside diameter from the thread. This is of particular value in connection with the outside clamping or sizing ring, as it assists in adjusting the several prongs of the die equally, as well as making it unnecessary to provide undue freedom in the die-holding device.

On large work, where inserted chaser dies may be utilized, it is evident that more than three cutting edges can be used with very little of the difficulty common to the spring-screw die, as distortion due to hardening is less, and if it exists at all, it can be compensated for if necessary. Furthermore, the desirable side clearance to each chaser may be readily given to this type. Where more than three teeth are found desirable, it is always better to have an odd than an even number of teeth, as the possibility of only two teeth cutting is then avoided.

Making Inserted Chasers.—With inserted-chaser "opening dies" it is becoming common practice to mill the threads of the chasers with a milling cutter, thus giving straight and ample clearance, instead of hobbing with a master tap which gives very little clearance unless greatly oversized.

A feature emphasized by those milling chasers, instead of hobbing, is that when dies or chasers are cut by a master tap, there are three inherent errors which if cumulative may be sufficient to make it impossible to obtain perfect pitches. There is first the error of the lead screw in the lathe used in cutting the master hob; second, the error in the hob due to hardening; third, the error in the die or chasers due to hardening. If these three errors act cumulatively the result is that an inaccurate die is produced. By milling the chaser, the first two errors may be eliminated, leaving only the error caused by hardening the chaser, and this last error may be kept small by hardening only the cutting edge, the unhardened material at the rear having an important effect in preventing distortion.

It is furthermore advanced by some that in milling the thread of a chaser the metal is not compressed as it is with a tap; that with a tap the metal is not really cleanly cut, but is, so to speak, more or less pushed off as the tap has no clearance and the resulting surface is left in a state of strain which relieves itself when

hardening, thus increasing the distortion both in form and in pitch.

Button Dies.—The shape of the round button die gives it an advantage over the spring-screw die in hardening, and this type of die is in considerable favor with many on small work. It is not considered so convenient to resharpen correctly as the spring-screw die, but the low original cost of button dies permits them to be discarded when dull. Chips on coarse pitches are not so easily gotten rid of with the button die as with other types. It has, however, when correctly made, some very good features, and when fully understood and made in proper manner, it is very satisfactory for screws 5/16 in. in diameter and under. Owing to the rigidity of the button die, the cutting edge of the tooth may

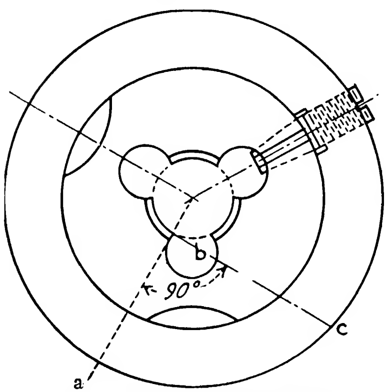


FIG. 97.—Typical button die.

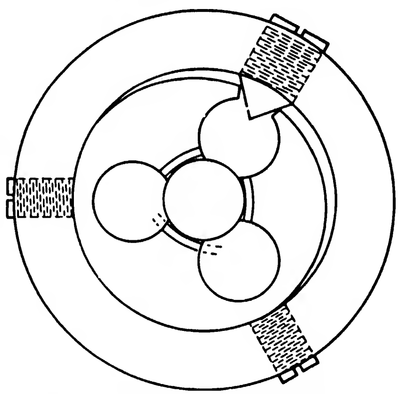


FIG. 98.—Cut with a large hob.

always be ahead of the center for brass, as well as for steel, and good results follow.

This type of die should be made substantially as in Fig. 97, and instead of hobbing with an oversize hob, an undersize hob is superior, the die being expanded to proper cutting size. The reason for this is that, with the cutting edge of the teeth *ahead* of center and provided an oversize hob be used, the relation of the cutting edge to the work would be as shown in Fig. 98, when *closing down* the die which, when exaggerated as shown, emphasizes the bad cutting action that exists under normal conditions to an objectionable extent. When the die is *expanded*, as shown by Fig. 99, the clearance of the threaded portion of the die is in the center, where it is desirable that it should be, and the cutting

action is excellent. When reversing the work for the removal of the die, there is no danger of the wedging in of chips.

This type of die, on account of the chance it affords for what would ordinarily be considered an excessive rake without springing, is found very satisfactory for cutting copper.

In the button die, as shown in Fig. 97 and in Fig. 99, it should be noted that the expanding wedge is a taper pin

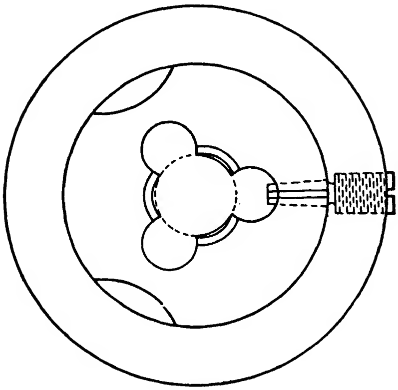


Fig. 99.—Cut with a small hob.

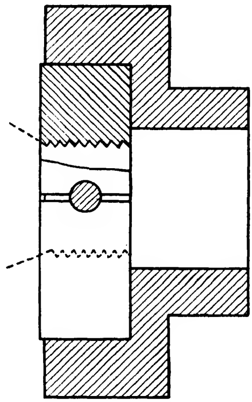


Fig. 100.—Chamfered for lead.

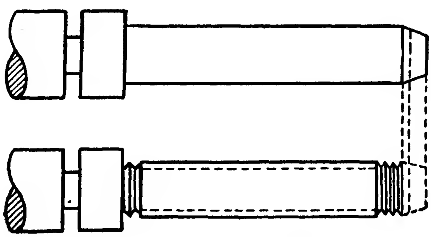


Fig. 101.—Cutting off chamfered end.

which acts as a tie and prevents a twist to the die which might occur from hardening if a wedge were used as in Fig. 98. The line *a*, Fig. 97, representing the cutting edge of the die, may be pointed on center or above, as desired, and then the center of hole *b* is located on line *c* so that the edge of the hole is tangent to the line *a*.

Application of Die to Work.—Most dies are chamfered, so as to cut smoothly and to assist in starting on to the work, as in Fig. 100, but sometimes it is necessary to cut very closely to a

shoulder with one die only, and in this event there can be but little chamfer. It will be of assistance in starting the die under these conditions, when work permits, to bevel the end of the work as indicated in Fig. 101, prior to running the die on, and afterward remove the bevel, if objectionable.

It sometimes happens that very short threads have to be produced, as shown at *A*, Fig. 102. An effective method of producing such work is to first cut a long thread and afterward face off the extra portion between neck *B* and the end of the piece. The nicking at *B*, previous to cutting the thread, is necessary to prevent a burr, which would otherwise be produced by the facing tool.

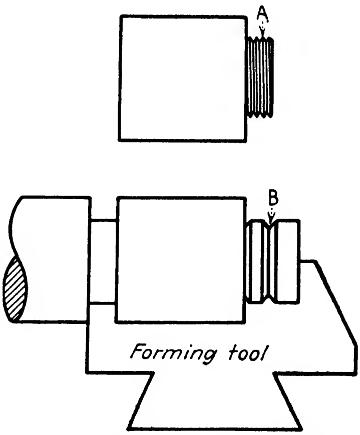


Fig. 102.—One way of getting a short thread.

There are various types of screw-machine dies besides those already referred to. In Fig. 103 a Brown and Sharpe tap holder is shown which is made in similar form for dies. This releasing holder is of value where it is required to thread close to a shoulder or tap to the bottom of a hole. In operation, the holder draws

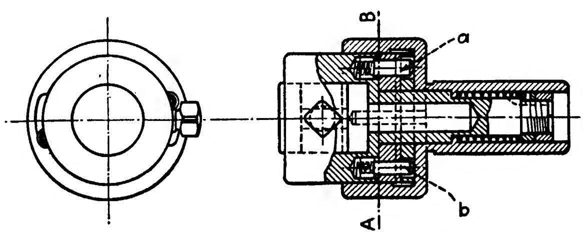


Fig. 103.—Reversing tap and die holder.

out until the spring plungers *a* and *b* are pulled from the holes in the plate. The body then revolves freely with the work until the machine spindle reverses. As soon as the body starts to revolve in the opposite direction, two steel balls are thrown out by centrifugal force and by wedging action prevent further rotation and the tap or die unscrews from the work.

Of different forms of opening dies, one is shown is Fig. 104. This is the Geometric *DS* intended primarily for use on Brown and Sharpe machines. It is sensitive and constructed to give accurate threads without stripping or shaving threads at high speeds. It has a floating shank and uses special tripping and resetting devices. The floating shank allows the head to yield slightly when starting on the thread and insures a smooth thread from the start without necessity for close camming for lead. The adjustable trip lever insures sensitive tripping action to prevent stripping and shaving and the adjustable feature through two check nuts enables the die to be set simply for the desired length of

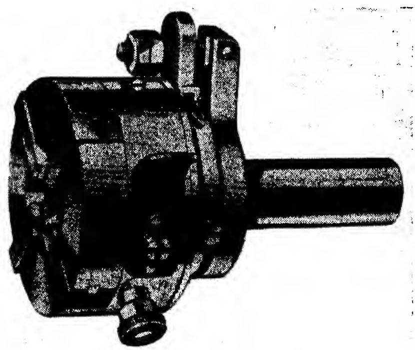


Fig. 104.—Geometric die head.

thread. The head opens and closes automatically through the adjustable trip and the closing attachment, which may be used to make contact directly with the bed of the machine, or a special stop may be mounted to close the head as it comes up into operating position.

Internal Threading.—Thus far this chapter has been confined to the external threading of work. It should be remembered that many of the conditions are common to internal threading operations also.

Taps have their cutting edges cut radially in most cases, though on brass it is desirable to cut below center, thus breaking up the chip for its more easy removal. A free curling chip is undesirable when tapping, unless the stock is of such a nature that tearing of work will result in case the cutting edge is not such as to produce such a chip. Copper is a material of this nature, and a tap made

like Fig. 105 with a big rake to its cutting edge works out nicely. On copper and similarly acting material, cutting out every other tooth, as is done on the Echols patent tap made by the Pratt & Whitney Company, is found an efficient means of producing clean threads. Figure 106 illustrates this tap and also shows it entered in a piece of work; Fig. 107 represents an ordinary tap.

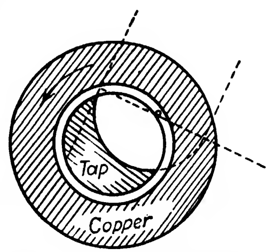


FIG. 105.—Special tap for copper.

In the former (which is always made with an odd number of flutes), each alternate tooth is omitted, the arrangement being so carried out that each of the cutting teeth is followed by a space and each space by a tooth. This arrangement gives a freedom of action to each cutting tooth not obtainable with the ordinary form of tap. In tapping holes with ordinary taps in copper and similar material the tendency is to tear the threads, owing to the wedging action of the cutting teeth, and the slight

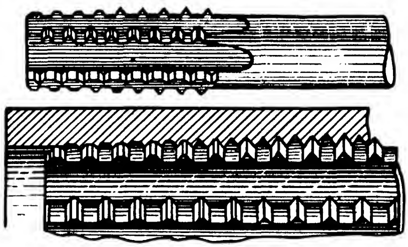


FIG. 106.—The Echols tap.

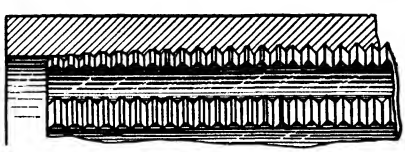


FIG. 107.—Regular tap in same work.

resistance offered by the metal to the pressure of the continuous row of cutting edges. The chips are carried forward in a mass in front of the cutting teeth, and unless the tap is frequently reversed, thus breaking up the mass of chips, either the thread will be mutilated or the tap broken.

It will be seen upon examination of Fig. 106 that only one side of the thread that is being formed with the tap there shown is operated upon at once. It is thus relieved of one half the pressure and wholly of the wedging action, and because of the absence of the next adjacent threads, a slightly lateral movement of the thread being formed is possible, owing to the mobility of the metal. It is probable that under similar conditions the removal of alternate teeth in a die would be of value.

Length and Number of Lands.—The number of teeth in regular taps and width of land should be regulated by the diameter and pitch of work as well as the nature of the material being cut. On "sticky" material both dies and taps should have relatively short land. On fine threads, where a drunken thread is to be insured against, more teeth are required than on a coarser pitch of the same diameter. A good average number of teeth on taps for United States standard threads is given in the following schedule. Too few teeth and too short land afford very little support and may cause chattering; too much land in contact causes heat due to excessive friction and welding of chips, torn threads, etc.

Outside diameter	No. of flutes	Width of land
3/16	4	3/64
1/4	4	1/16
5/16	4	5/64
3/8	4	3/32
7/16	4	7/64
1/2	4	1/8
5/8	4	5/32
3/4	4	3/16
7/8	4	7/32
1	4	1/4
1 1/4	4	5/16

Tap Relief.—Taps for use in the screw machine should permit reversing of the work without any chance of chips wedging at this point, and consequently are not cleared the same as hand taps which go entirely through the work and are thus removed without reversal.

Figure 108 illustrates the way to relieve the top and sides of the teeth of screw machine taps. A tap for long cylindrical threading

should in addition be slightly tapered toward the back so as to free itself. This taper should be about 0.020 to 0.030 in. per foot, although conditions may make it desirable to vary this somewhat.

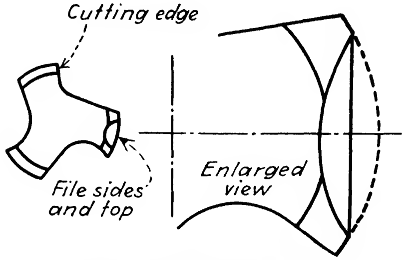


FIG. 108.—Relieving tap friction.

Where a tap is used on steep triple and quadruple threads, it is customary to cut the flute on a helix so as to present a square cutting face like Fig. 109, which is self-explanatory.

Sizing Work for Threading.—In boring holes previous to tapping they should be somewhat larger than the theoretical diameter at bottom of thread, as the crowding action of the tap will cause the metal to flow a little and compensate for this. Where no allowance is made, frequent tap breakage is liable to occur as well as torn threads in the work. On external work it is for the same reasons advisable to turn the work undersize; the table shown at the top of page 292 gives good average allowances for both internal and external work.

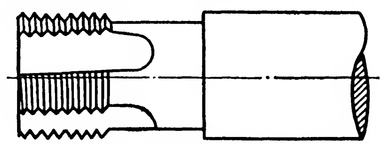


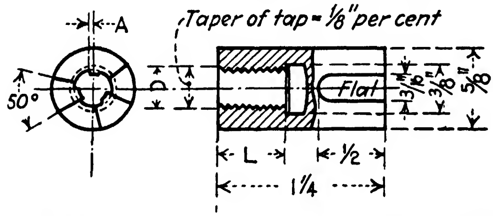
FIG. 109.—Angular cutting edges.

Spring-die Sizes.—It may be of value to include a table of suitable dimensions for spring-screw dies, and the data in the sketch, Fig. 110, should prove of service, particularly for steel. For brass the cutting edge is radial, thus eliminating dimension A. The width of land at bottom of thread is usually made about $\frac{1}{4}$ outside diameter of cut, the milling between flutes being 70 deg. for the flute and 50 deg. for the prong in the case of three-flute dies.

Sizing Dies and Taps.—Almost all dies have means for slight adjustment; it is not necessary to use the same care in sizing

Threads per inch	External work, turn undersize	Internal work, increase over theoretical bottom of thread
28	0.002	0.004
24	0.002	0.0045
22	0.0025	0.005
20	0.0025	0.0055
16	0.003	0.006
14	0.003	0.0065
13	0.0035	0.007
12	0.0035	0.007
11	0.0035	0.0075
10	0.004	0.008
9	0.004	0.0085
8	0.0045	0.009
7	0.0045	0.0095
6	0.005	0.010

them as in the case of taps which are generally nonadjustable. Dies may be "chased out" to fit a male-threaded plug and a



D =	1/16	1/8	3/16	1/4	5/16	#3	#4	#6	#8	#10	#12
Th'ds P.I. =	64	40	32	20	18	56	40	32	24/32	24/32	24/32
$A = \frac{D}{10}$	.006	.012	.019	.025	.031	.010	.011	.014	.016	.019	.021
L =	3/16	9/32	3/8	1/2	1/2	7/32	1/4	9/32	5/16	11/32	3/8

D =	3/8 to 1/2	1/2 to 3/4	3/4 to 1
Th'ds P.I. =	Std.	Std.	Std.
A =	D ÷ 10	D ÷ 10	D ÷ 10
L =	3/4	1"	1 1/2
O.S. Dia.	1"	1 3/8	1 5/8
Length	2"	2 1/4"	2 1/2"

Fig. 110.—Spring-die dimensions.

tap to suit a female gage. In the event of having only a plug or a sample to work to, the ball-point micrometer is very con-

venient in comparing diameters when cutting the thread on a tap. In making taps to a drawing or specification, it is of assistance to turn a portion of the tap to the theoretical bottom of the thread and then with properly formed threading tools, to use this part as a gage when sizing the tap, either copper plating with blue vitriol and burnishing the plate with the thread tool or dispensing with the plating and using a good eyeglass to detect when actual contact between the threading tool and tap blank at gage-point takes place.

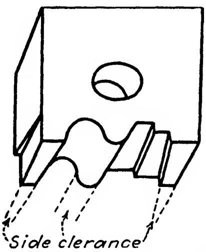


FIG. 111.—Flat-formed blade.

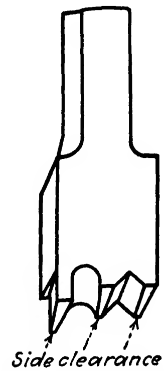


FIG. 112.—Solid forged cutter.

Testing Threading Action.—When in doubt as to the proper cutting action of a die or tap, it is advisable to carefully turn or bore a piece of work, then thread the work under normal conditions. Now stop the work with the cutting action taking place, and in the case of external threading, note whether all the cutting edges are producing an even clean chip, or pushing the thread off. In case the thread in the die is smooth and the cutting edges are sharp and have been properly lubricated and the work is poor, the chances are that the angle of rake or the clearance is at fault.

FORMING TOOLS AND METHODS OF MAKING THEM

A number of types of cutting tools and holders have been developed for cross-forming work on the automatic screw machine.

For brass work flat-formed blades such as shown in Fig. 111 or solid forged tools as in Fig. 112 are found very satisfactory, owing to its being possible to obtain with these perfect side and peripheral clearances.

Where frequent sharpening of the tool is required and where the form produced must be kept uniform, these tools are not always satisfactory, and a tool whose cutting edge can be sharpened without any alteration to its contour is generally preferred. Figure 113 illustrates what is usually known as a

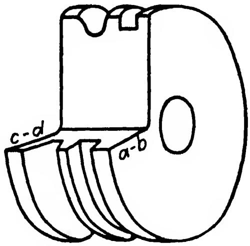


FIG. 113.—Circular forming tool.

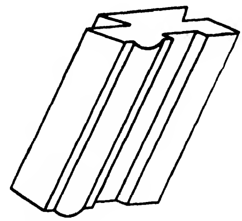
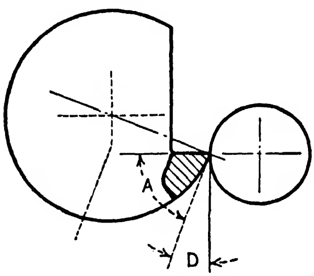


FIG. 114.—Dovetail forming tool.

circular forming tool. The grinding is done on face *abcd,* the form as indicated extending entirely around the periphery. Figure 114 illustrates another type of forming tool which admits of the cutting edge being reground without alteration of its contour. This is known by various names, a very common one being "dovetail forming tool" from the fact of its generally having a dovetail to fit into its holder. To prevent any confusion this tool will be referred to as a dovetail forming tool hereafter in this chapter. These tools are generally held and fed in such a manner that the cutting edge is on a radial line with the work being formed. In some special cases, however, it is found more satisfactory for the tool to travel tangentially to the work instead of radially.



Dotted line is clearance angle of circular tool and corresponding edge of Dovetail tool
Cross hatched space indicates metal in circular tool to conduct away heat
A *indicates metal in Dovetail tool to conduct away heat*
D *Amount of clearance at cutting edge*

FIG. 115.—Comparison of two tools.

Comparison of Types.—These are various things to be taken into consideration when determining whether to use a circular of a dovetail forming tool, and the following points may be of assistance when making the decision:

1. The peripheral clearance angle being constant in both circular and dovetail tools, as shown by Fig. 115, it is clear that in the dovetail type there is more metal directly under the cutting edge than in the circular tools to conduct away the heat which is produced while forming.

2. The difficulty and cost of producing an accurate and smooth form leave much in favor of the circular forming tool.

3. The type of tool post required for a circular forming tool oftentimes interferes with turret tools simultaneously operating on work with the cross-slide tools. The dovetail type of tool permits of the use of holders which do not thus interfere.

4. The increasing peripheral clearance of a circular forming tool permits a lesser angle to be utilized at the point of cutting

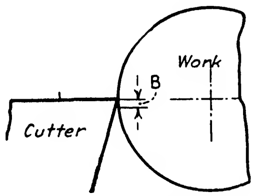


FIG. 116.—Lessening cutting angle.

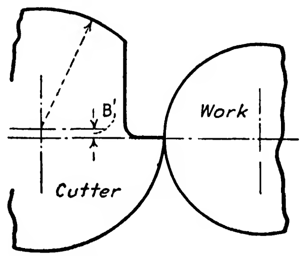


FIG. 117.—Changing clearance by height of cutter.

than with the dovetail type, and this lesser angle has a tendency to prevent chattering on account of the support afforded. With the dovetail type, stoning the clearance face is sometimes resorted to, which in effect gives a lesser angle at the cutting point, as indicated in Fig. 116 at *B*.

A similar result with the circular tool *without* stoning the clearance edge is obtained by properly determining the relation of the center of the cutter to the center of the work as shown at *B'*, Fig. 117. Raising or lowering the cutting edge of the tool changes the clearance angle and incidentally changes the form produced. Consequently the clearance angles and the relation of the center of the cutter holding bolt to the work center are points which it is necessary to consider carefully.

Diameters and Clearances.—With a given material, the larger the diameter of the work the greater the angle of clearance required. Clearance angles are seldom less than 7 deg. and seldom over 12 deg., except on work out of the ordinary run.

The diameter of circular forming tools is an important point to consider. A small diameter has a more pronounced change of clearance angle than a large diameter. In fact, when of an exceedingly large diameter, the circular tool approaches in cutting action the dovetail type of tool.

On the Brown and Sharpe automatic screw machines the standard outer diameters of circular forming cutters are as follows:

Nos. 00 and 00G machines, 1¾ in. O. D. cutter.

Nos. 0 and 0G machines, 2¼ in. O. D. cutter.

Nos. 2 and 2G machines, 3 in. O. D. cutter.

In order to obtain suitable peripheral clearance the practice is to locate the center of the cutter above the center of the work as at *C*, Fig. 118, the tool holder being bored out above the center as indicated and the forming tool milled out below center a corresponding amount so that its flat cutting surface is level with the center of the work. The amount to locate the circular tools above center and cut their working edges below for the machines just referred to is as follows: For Nos. 00 and 00G, machines 0.125 in.; Nos. 0 and 0G, 0.15625; Nos. 2 and 2G, 0.250 inch.

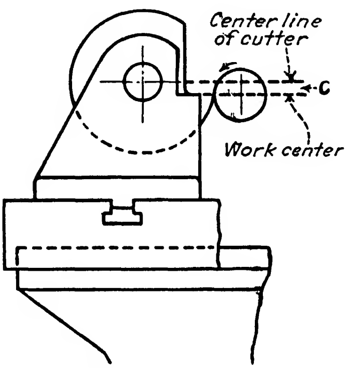


FIG. 118.—Locating the cutter.

Getting the Tool Diameters at Different Points.—In order to produce a circular or a dovetail type of tool so that the contour of its cutting edge is such as to produce correct work, the amount a circular tool is off center as *C* in Fig. 118 and the clearance angle of a dovetail tool as at *D*, Fig. 115, must be known. In connection with the circular type of tool the diagrams Figs. 119 and 120 will be found convenient for quickly ascertaining the diameters of the various sections of the tool.

When two or more diameters are required on a circular forming or cutting-off tool to produce corresponding sizes on the work, the difference in diameters of the tool is less than the difference on the work, because the cutting edge of the tool is parallel, not radial, to the center of the tool.

The relative difference increases more as the smaller diameter decreases. The cutting edge is below the center line of the tool, as in Fig. 115, to give proper cutting clearance on the front of the tool, the amount being greater as the capacity of the machine, or size of tool increases. One method of calculating the diameters for a tool is as follows:

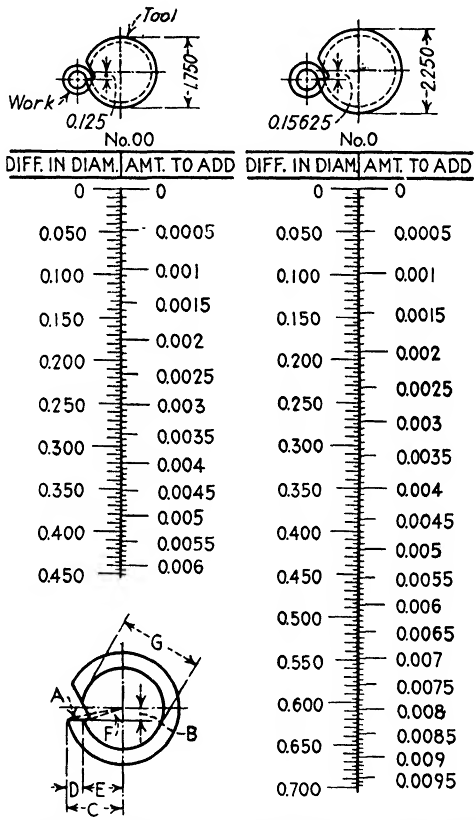


FIG. 119.—Tools for No. 00 and No. 0 B. & S. machine.

In a right-angle triangle (Fig. 121) the short side B equals the amount the cutting edge is below the center of the tool; the hypotenuse A equals the radius of the tool. Find the long side C, which is the horizontal distance from the cutting point to the vertical center line.

From this dimension as a constant, subtract half the difference in diameters of work D. Take the remainder E as the long side of a new triangle using the same short side B, as before,

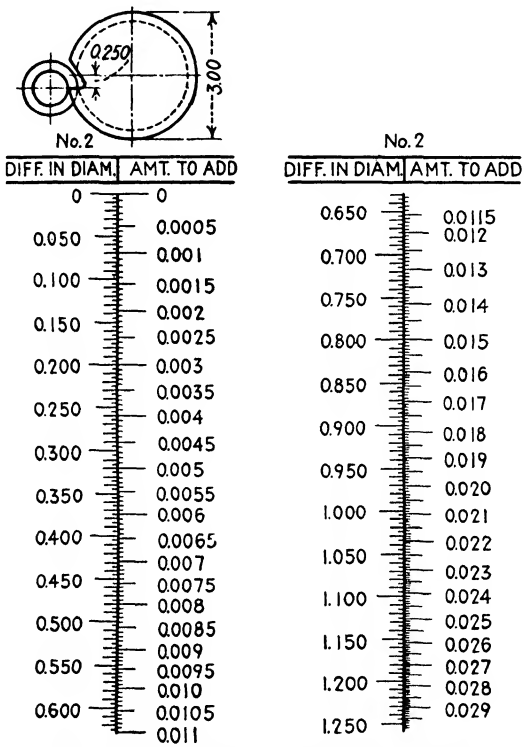


FIG. 120.—Tools for No. 2 B. & S. machine.

and find hypotenuse F or the new radius, which, doubled, gives the corrected diameter G for the tool (Fig. 119).

Formulas:

A = radius of cutter

B = distance of cutting edge below center of the tool.

C = distance of cutting point from vertical center of tool = $\sqrt{A^2 - B^2}$.

D = half the difference of the diameters of work.

$E = C - D$.

$F = \sqrt{E^2 + B^2}$.

$G = 2F$ = corrected diameter.

The comparative scales (Figs. 119 and 120) have been calculated and laid out in a clear and convenient manner for Brown and

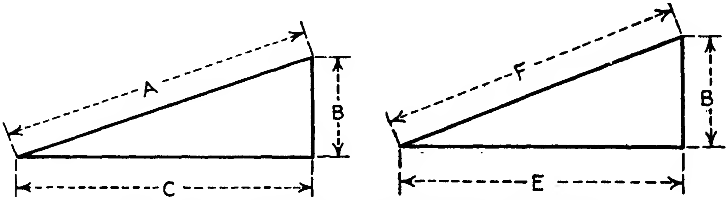


FIG. 121.—Triangles for calculating tool diameter.

Sharpe automatic screw-machine circular tools and will save a great deal of time in getting the dimensions of these tools.

Example.—Form tool for No. 2 automatic. Outside diameter of tool = 3 in.

The difference in the diameters of work, 0.375 and 0.625 = 0.250; the apparent second diameter of the tool = 3 − 0.250 = 2.750; the amount to add to the apparent diameter corresponding to the difference 0.250 is found in Fig. 122. Opposite 0.250 on the scale under the heading "Difference in diameter" is given "Amount to add" = 0.0038. The corrected second diameter = apparent diameter plus allowance = 2.750 + 0.0038 = 2.7538. The difference in diameters of the work 0.375 and 1 = 0.625; the apparent third diameter of the tool = 3 − 0.625 = 2.375. The amount to add to the apparent diameter corresponding to the difference 0.625 = 0.0109. The corrected third diameter = apparent diameter plus allowance = 2.375 + 0.0109 = 2.3859.

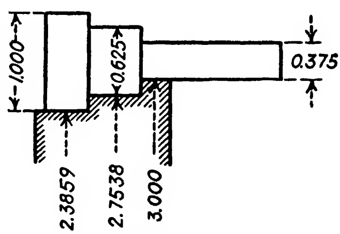


FIG. 122.—Example for cutter calculation.

Special Cases.—Where different diameters from those given in the diagrams are used, or when the amount the cutter center is set off from the work center varies from the diagrams, the following formula may be used in connection with Figs. 123 and 124:

$$f = g - \sqrt{g^2 + a^2 - (2a\sqrt{g^2 - c^2})}$$

To compute the measurement T on dovetail tools, Figs. 123 and 124, the formula would be:

$$T = a\ (\cos A)$$

Ten degrees is a very common clearance for dovetail tools; cos 10° = 0.98481.

Tool-making Methods.—There are various methods employed by the toolmaker in accurately making circular and dovetail forming tools. The form of tool has considerable to do with the scheme selected. For instance, if the work is entirely without curved or irregular outline the tool, if circular, would be simply turned up in an engine lathe to the correct dimensions, sometimes making allowance for grinding, and then milling out a section for the cutting edge. In case the cutter in question is of the dovetail form and has been correctly dimensioned, no difficulty will be experienced in accurately planning to dimensions

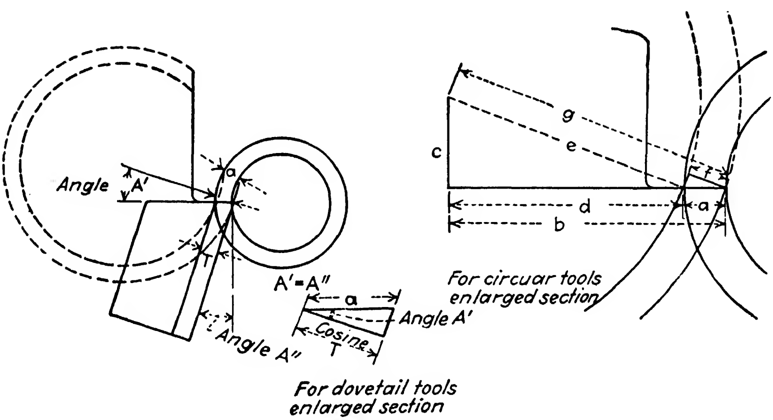


Fig. 123. Fig. 124.

Figs. 123–124.—Diagrams for dovetail and circular cutters.

if the toolmaker has proper-dimensioned size blocks. The depth micrometer also is of value in this work. Sometimes fly cutters are also used for making these dovetail tools.

The Transfer Scheme.—It sometimes happens that circular cutters are to be made which are very difficult to caliper; it is then quite frequently advisable to turn a tool-setting gage of the correct diameter and copper plate the gage (using blue vitriol), and then to size the cutter correctly by first bringing a master tool into contact with the gage, noting the graduation on the micrometer collar on the feed screw of the lathe, then moving the carriage longitudinally and bringing the master tool down upon the cutter to the same position. This scheme admits of several master tools being used, and in connection with microme-

ter stops or suitable size blocks for the longitudinal movement of the carriage accurate circular tools can be economically made.

Figure 125 illustrates this transfer scheme, numbers indicating corresponding diameters of model and cutter. By simultaneously using a fixed dead tool arranged as a stop on center against the gage before referred to and a master tool off center the amount the circular cutter is off from the work center, the gage may be made of such diameters as would be correct with the cutting edges of the circular cutter on the radial line instead of being off center. Another modification of the scheme is to dispense with the dead tool or stop referred to and use a rigid master-tool-holding block capable of rapid vertical adjustment which will permit of setting the master tools to the gage while on center and then allow them to be dropped below center an amount equal to the amount the cutting edge of the cutter is off center. This

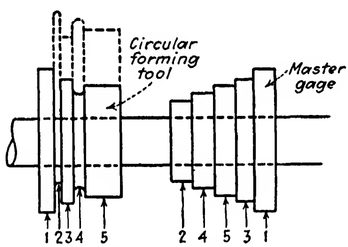


FIG. 125.—Laying out tools.

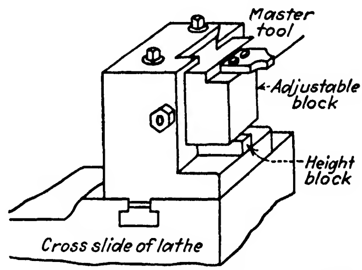


FIG. 126.—Adjustable tool holder.

permits very accurate cutters to be produced. Figure 126 will give an idea of this method.

Sometimes it is found convenient first to rough out the circular forming tool and next mill out the space for the cutting edge, and thus permit the master tool to be used without the chance of error creeping in which might occur on account of the necessity of moving the cross slide of the carriage in and out.

It will be found of advantage to use tissue-paper feelers between the master gages and the tools in these transfer methods. Some toolmakers prefer merely copper plating the master and just burnishing the copper surface to show contact previous to transferring.

Master Tools and Templets.—When irregular-shaped circular forming tools are produced by direct micrometer measurements, the master tool is generally made of the same contour as the work

that is to be produced. Consequently the master tool when finishing the circular tool must be held off center an amount equal to the amount the cutting edge of the circular tool is off center. The sequence of operations in making a circular tool from a given model or drawing is shown in Fig. 127. First is prepared a master-tool templet *A*, and then a master tool *B*. The templet is of sheet steel and should be made from a rectangular piece that is perfectly square to facilitate measuring with a micrometer. Considerable skill is required to file complicated forms accurately.

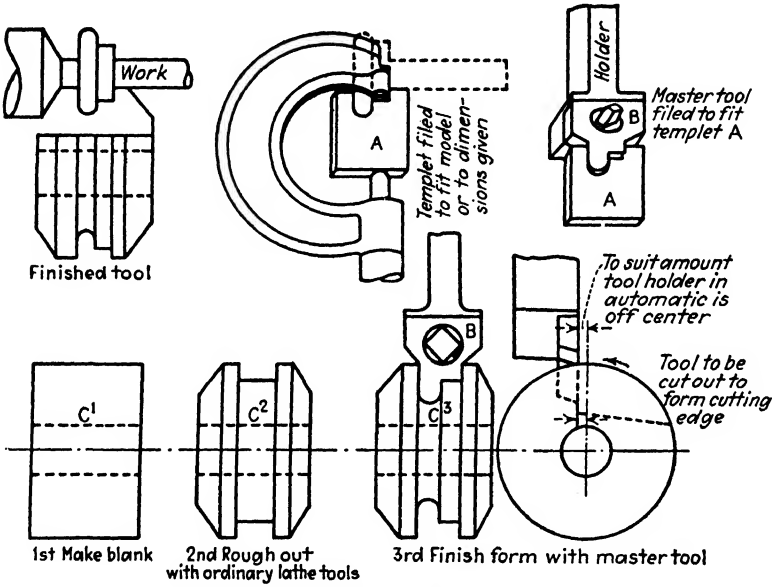


Fig. 127.—Making circular forming tools.

The master tool *B* is shaped exactly to fit the master-tool templet *A*, and is also made perfectly square to permit measuring with a micrometer.

The circular tool is formed by the latter as previously outlined and as shown in Fig. 127. Owing to the thin scraping chips taken when finishing a cutter to exact size the master tool may have a tendency to glaze instead of cutting. The use of turpentine prevents the glazing by assisting the tool to take hold on very thin chips. In some cases two or more master tools are found more convenient than the one, especially in making wide circular forming tools, and in this event it is customary to make a male

sheet-steel gage *D*, Fig. 128, for convenience in testing the longitudinal positions of the various cuts in the circular tool. This latter gage does not require the complete form as it is commonly used for longitudinal work only.

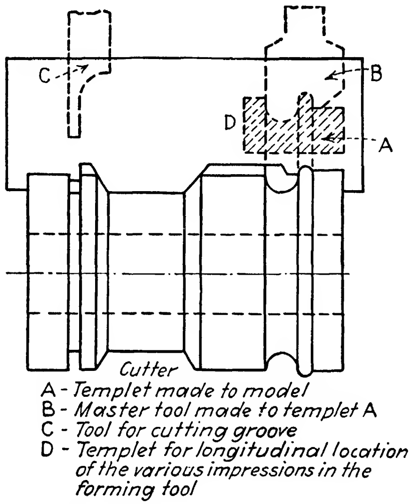


FIG. 128.—Templet for cutter.

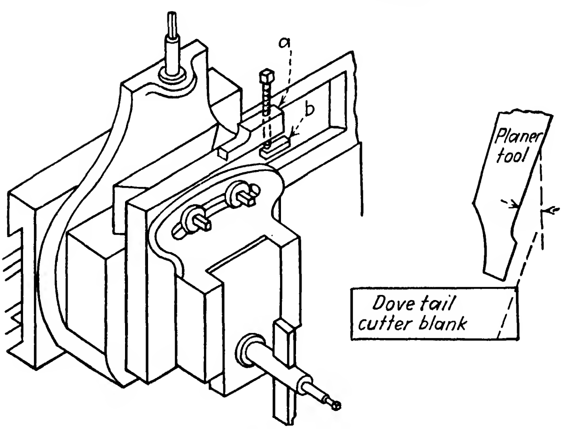


FIG. 129.—Planing dovetail tools.

Making Dovetail Tools.—In planing dovetail tools size blocks may be used as already mentioned for setting the planer or shaper tool to the various heights required. A stop screw may be located as at *a*, Fig. 129, and size blocks used as at *b* for regulating the set-

ting of the head. Or a depth micrometer may be used instead of the stop screw, tissue-paper feelers being used in either case. Size blocks may also be used directly on the plate in many cases, the tool being brought down into contact with the different blocks for getting the depths of the various grooves, etc., in the cutter blank.

In using a formed tool of same contour as the model in planing the dovetail tool as in the enlarged sketch in Fig. 129, the formed

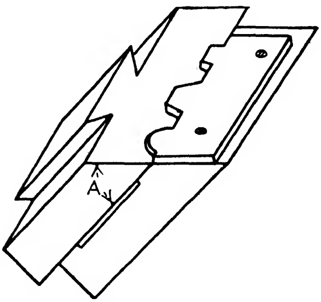


Fig. 130.

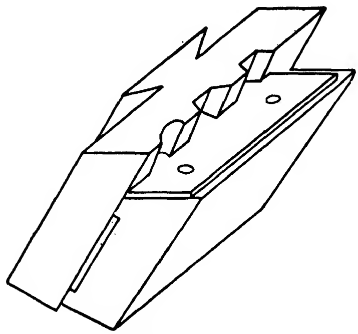


Fig. 131.

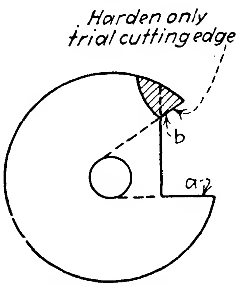


Fig. 132.—Method of testing cutter.

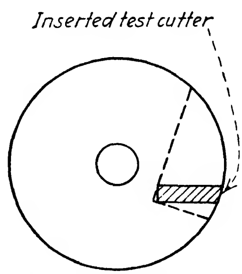


Fig. 133.—Another test method.

tool is held in the post at the same angle as the dovetail tool will afterward be used on the work. The dotted lines indicate the angle to which the working edge will be finished and the planing tool is shown set at the same angle.

In planing the dovetail form of tools it will sometimes be found of advantage to plane the face of the cutting edge of the blank to the correct angular relation to the clearance face as at *A*, Fig. 130, and then scribe the contour desired on this cutting face from a templet.

If the templet is fastened to a block as shown, the shape of the finished soft cutter may also be nicely tested as in Fig. 131.

As frequent hardening and annealing of tool steel is liable to affect its quality, various expedients are resorted to in order to test the correctness of tools without undue waste.

Testing Outline of Forming Tools.—A common scheme is to mill the circular tool as in Fig. 132, where *a* is the actual cutting edge and *b* a trial cutting edge. The cutter is hardened at *b* only and a piece of work is formed by this edge. If incorrect, the cutter edge is annealed at that point and then corrected. Another method is to insert a flat piece of steel as in Fig. 133, and after forming, the test piece is removed and hardened to test the accuracy of the form in the cutter.

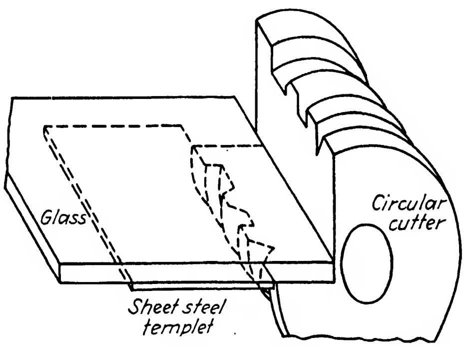


FIG. 134.—Checking contour of cutter.

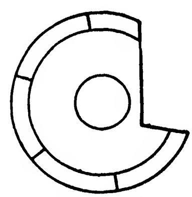


FIG. 135.—Slots help prevent fire cracks.

A glass plate is frequently found convenient when testing the outline of a circular tool with a templet, the sketch (Fig. 134) showing the application clearly.

Narrow circular cutting-off tools and in fact almost all delicate circular forming tools which are apt to be cracked by hardening are benefited by having radial slots milled as shown in Fig. 135; they are then less liable to crack than when left solid.

Forming and Turning.—There are a number of important details regarding the shape and method of using forming tools some of which will now be touched upon. Sketches A, A^1, A^2, Fig. 136, indicate a method of forming and cutting off a piece with two tools, one of which is, of course, fed into the work before the other. The burrs indicated by arrow points at A^2 are due to the rubbing of the forming tools on the side cuts, and unless there

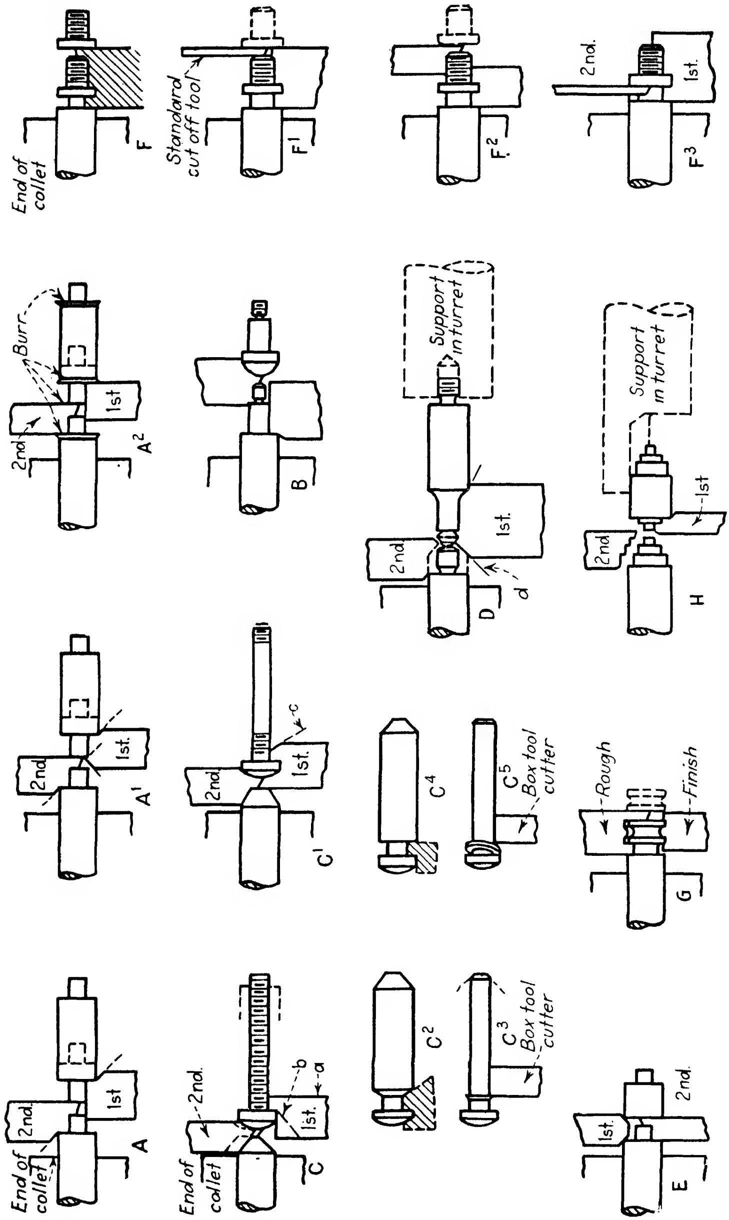


FIG. 136.—Details of operations in turning and forming.

is perfect side clearance to the forming tool, the burr will be increased. By adding a bevel edge to the tool, as shown by A, the burr produced is removed. A^1 is a refinement over A. At B is illustrated a common method of simultaneously cutting off and forming shoulder screws, the two tools finishing their cuts at the same time. Where a machine with single cross slide is used for producing work in this fashion, the cutting-off tool should precede the forming tool as the bar then has its full diameter and strength for the cutting-off operation. Sketches C to C^5 show an ordinary screw in which the head is to be formed by cross-slide tools and the body turned by a box tool or hollow mill in the turret. The cross-slide tools start their cuts together, but the forming tool for the head, of course, has to finish first. The cutting-off tool should be made so as to bevel the end of the bar as shown, in order to permit the starting of the box tool on a light cut until its back rest has a good support.

The forming cutter for the head should be beveled as at c in C^1 in case the box tool follows the forming cut. This allows the tool to cut into the stock as at C^2, leaving a beveled shoulder so that when the box tool is fed along it completely removes the superfluous metal without leaving an objectionable ring which is quite apt to be produced under the conditions represented in C^4 and C^5. The ring of metal there seen, which is a result of the square shoulder cut by the forming tool in C^4, is quite apt to tip over on the screw blank and cramp and to later on prevent the die from cutting the thread properly.

Supporting Long Work.—At D is illustrated a method of forming and cutting off long pieces where it is generally advisable to use a supporting device as indicated. It is obvious that the two cross-slide tools are not used simultaneously in this case. The bevel at d left by the first tool prevents the work breaking off prematurely. E is a very simple piece to produce. Where there are double slides on the machine, the two tools may start their cuts at the same time, but the rear tool, of course, merely chamfers the edges of the work. This bevel cutter is a refinement not always required, but it is desirable when the burr which would be produced by the front tool is objectionable.

Arrangement of Circular Tools.—In Fig. 137, sketches J, K, L, M show various ways of arranging forming tools with reference to the direction of rotation of the spindle. These are to be con-

sidered as being viewed from the turret, looking toward the head spindle. The arrangement at *J* is a most common one when a spring-screw die or a tap is to be used. The low-speed forward drive of the spindle is used for the cross forming of the work (as at C-C^1, F-F^3, Fig. 136), while the high reverse speed is utilized for removing the die or tap and for light cutting-off cuts like that at F^2. At *K* is a similar arrangement to *J*, and in some cases this is substituted for the former, particularly where the die or tap has a left-hand thread; the cutting-off tool is used at the front and the heavier forming cuts taken from the rear in this event.

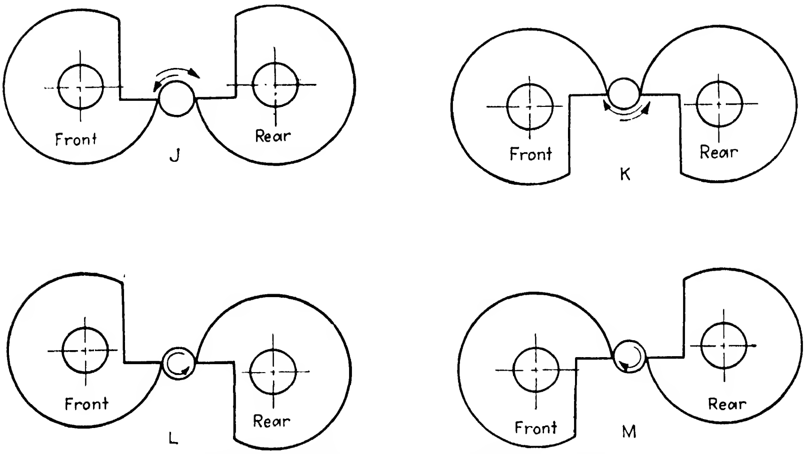


FIG. 137.—Form tools and rotation of work.

L and *M* show arrangements of tools where they operate simultaneously or where there is no necessity for reversing the direction of rotation of the head spindle. In this latter case the spindle speeds generally differ, and by carefully selecting the proper speeds a high rate of production will be possible. In all cross-forming work it is essential that the spindle fit snugly in its front bearing and that the collet or chuck has a good parallel contact with the bar which is being formed. A bell-mouthed collet is most frequently the cause of chattering, although excessive clearance may also promote chattering.

The tool holder should be of such design as to hold the tool firmly and the cross slide of such dimensions and so gibbed as to permit of no spring or shake. With careful attention to these details and providing the cuts are supported from the turret when

they are wide, and also providing the design of the tool and the question of clearances are carefully considered, excellent results should be obtained.

The rates of feed and the subject of lubricants are discussed in other chapters of this book. Obviously speeds, feeds, and lubrication all have an important bearing on results obtained in the automatic.

CHAPTER XVII

MISCELLANEOUS TOOLS AND METHODS

A number of illustrations are presented in this chapter applying to tools, cams, and methods of making them for use on screw machines. Much of this information is applicable to tools to be used on hand machines and turret lathes as well as on automatic screw machines. Forming tools are often of the same type as used on both classes of machines, the differences being usually in size and, in the case of circular tools, in the amount the tool is cut below the center. Figures 138 to 143 cover additional forming tool formulas. The points in camming included here are of course for the automatic only.

Pullouts for Drills.—In laying out a set of cams for the Brown and Sharpe Nos. 00, 00G, and 2G automatic screw machines, it is often necessary to have one drill enter the work farther than its recommended depth. So that the job may run without trouble, pullouts are usually provided for in the cams so that the drill can feed in for a distance of three or four times its diameter and then drop back sufficiently to clear the tip to permit the coolant to wash away the chips and cool the drill. The cam then advances the drill to the cutting position and the hole is drilled deeper.

When determining the cam spaces required for pullouts, it has been customary to draw that portion of the cam on either a blank cam or a layout sheet and to count the number of cam spaces needed. To obviate the necessity of drawing up each job the charts shown were developed. The only data needed are height of lobe before the pullout, the lowest radius of the pullout, and the estimated running time of the cycle.

Example 1.—Assume a job running in 15 sec., a height of the lobe before the pullout of 2 in., and that the drill must drop back ½ in. Refer to the chart, Fig. 144, for a 6-35 sec. cycle. Follow line L (lowest radius of pullout) to a radius of 1½ in. The corresponding number of cam spaces is 3½. Follow line H (height of lobe before pullout) to a radius of 2 in. The corre-

sponding number of cam spaces is 10. Subtracting L from H gives $6\frac{1}{2}$ cam spaces, the number required for the pullout.

Example 2.—Assume a job on the No. 0 machine, a cycle of 40 sec., a height of lobe before the pullout of 2.5 in., and that the

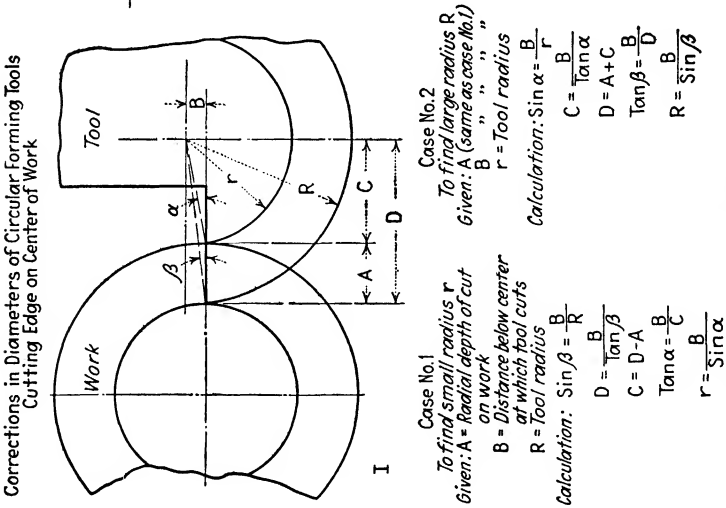


FIG. 138.—Corrections in diameters of circular forming tools.

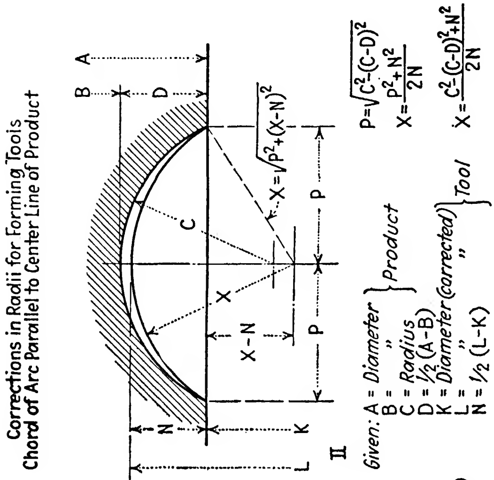


FIG. 139.—Corrections in radii.

drill drops back ½ in. Refer to chart, Fig. 145, for the 20-60 sec. cycle. Follow line L to lowest radius of pullout, or 2 in. (2.5 in.–0.5 in.). The corresponding number of cam spaces is 6. Follow line H (height of lobe before pullout) to ordinate of 2.5 in.

The corresponding number of cam spaces is 11. Subtracting L from H gives 5 cam spaces, the number required for the pullout.

Laying Out and Cutting Cams.—In laying out jobs for the Brown and Sharpe automatic, many plate cams must be made from time to time. To lay out a cam, it is necessary to determine how long each operation will require and to apportion

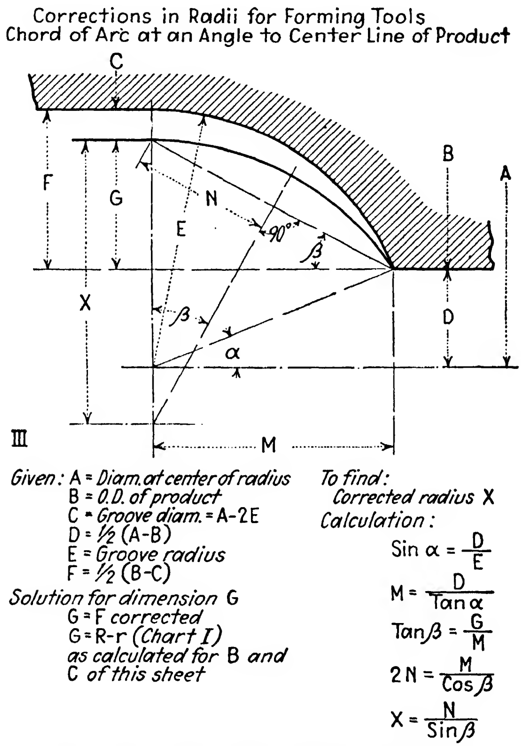


FIG. 140.—More radii correction formula.

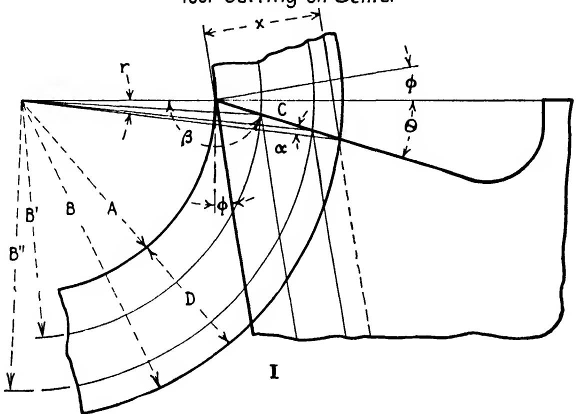
the stations accordingly. Each phase of the turret cycle must be figured to insure economical production. In this way the cross-slide gearing can be speeded up to cut down the time for a complete revolution of the turret cam to its most economical factor.

In Fig. 146 is illustrated the layout of a cam, showing the arcs required for each operation. The arcs are laid out in degrees or in any evenly divisible part thereof, so that the lobes can be

milled without complicated indexing movements. The same cam laid out in linear measurements is shown in Fig. 147, giving a better idea of the functions of the various lobes and the rises in decimal parts of an inch.

After the cam has been laid out, all the roller pockets should be milled, with the cam held in the machine vise with the jaws at right angles to the spindle and using an end mill of the correct

Corrections in Tool Profile
Flat Tool With Top Rake and Clearance Angles
Tool Cutting on Center



Given

ϕ = *Tool clearance angle*
θ = *Tool top rake angle*
β = *180° − θ*

2 *A* = *Small diameter work-A=radius*
2 *B* = *Large diameter work-B=radius*
D = *Step on work=B−A*

Calculation

$$\operatorname{Sin} \alpha = \frac{A \sin \beta}{B}$$

[Sin (180°-Angle)= Sin angle]

$$r = 180° - (\alpha + \beta)$$

$$c = \frac{B \sin Y}{\operatorname{Sin} \beta}$$

$$x = C \cos(\theta + \phi)$$

B' and B" denote intermediate steps on work and should be used for B in calculating corresponding correction

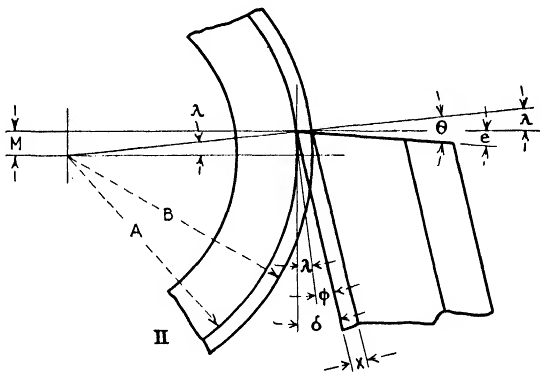
FIG. 141.—Top profile corrections.

diameter. At this time, much of the excess stock can be removed from other parts of the cam. The cam is next mounted on a mandrel held between the centers of the machine, and the lobes are milled by starting at the high point of each, using a cutter having a convex face. The cuts are made across the face of the cam at a right angle, indexing between cuts a given amount in degrees or fractions thereof. The machine table is, of course, raised a given number of thousandths for each indexing until

the lobe is completed. These cuts will leave the face of the cam with a lot of minute scallops, as shown at *A*, Fig. 148, which are filed out, the face of the lobe being afterward polished.

The reason for using a cutter having a convex face is that, as the table is raised, each successive cut in the lobe is higher from the centers than the face of the cutter, and if a cutter having

Corrections in Tool Profile
Tool Cutting Above or Below Center
Flat Tool



Given
A and B same as on chart I
M = Distance above or below center
δ = Tool clearance angle
e = Tool top rake angle

Calculations

Cutting point above center	Cutting point below center
$\sin \lambda = \frac{M}{A}$	$\sin \lambda = \frac{M}{A}$
$\phi = \delta - \lambda$	$\phi = \delta + \lambda$
$\theta = \lambda + e$	$\theta = \lambda - e (-)$ or $e - \lambda (+)$
$\beta = 180° - \theta$	$\beta = 180° + \theta$

Substitute these values in formula under "Calculation" on chart I and solve for "X" as usual λ must be less than δ or tool will not cut

Fig. 142.—Corrections for height of tool.

a flat face were used, it would cut into the cut previously made and ruin the contour of the lobe. The effect of using a flat-face cutter is indicated at *B*, Fig. 148. However, a flat-face cutter could be used if its edge were set adjacent to the part just milled, as indicated at *C*, Fig. 148. While this would eliminate interference, it would leave the face of the lobe with a series of fine ratchet teeth.

The lobes can also be milled by holding them on a mandrel in the dividing head, using an end mill, both the head and the

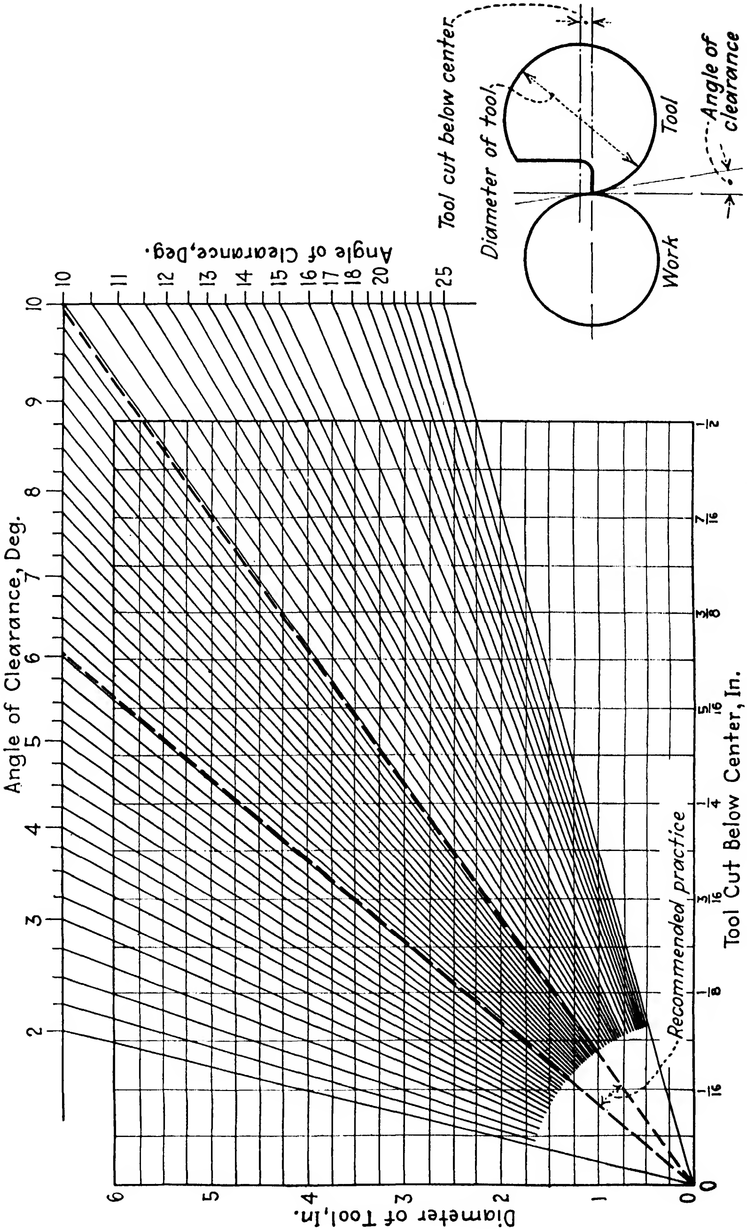


FIG. 143.—Another chart for tool calculation.

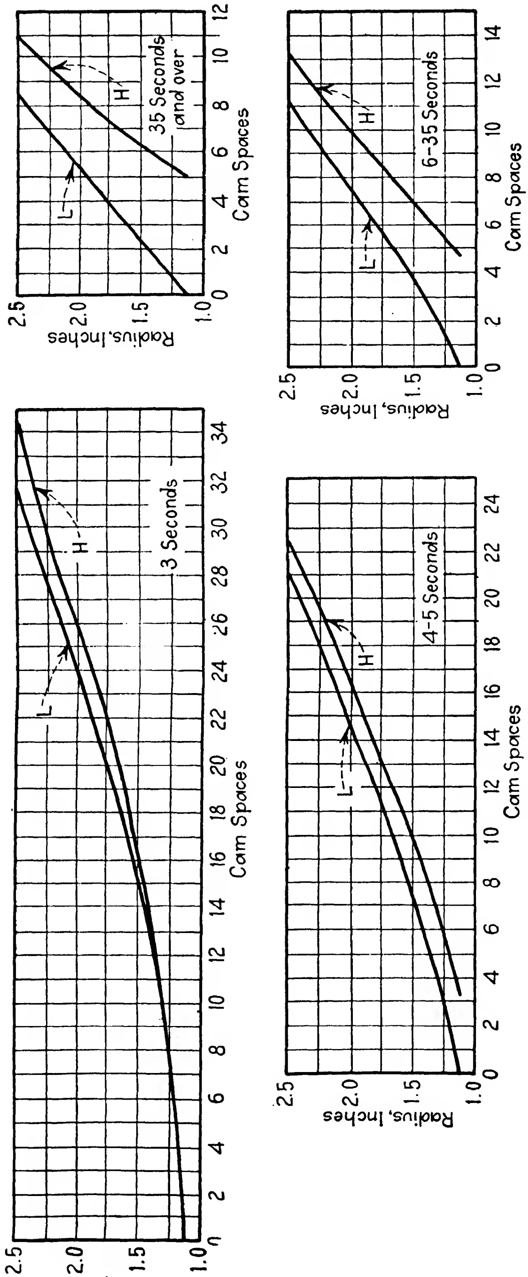


Fig. 144.—Chart of pull-out allowances for drills.

mill being set at predetermined angles (see American Machinists' Handbook, pages 408–426, 8th edition).

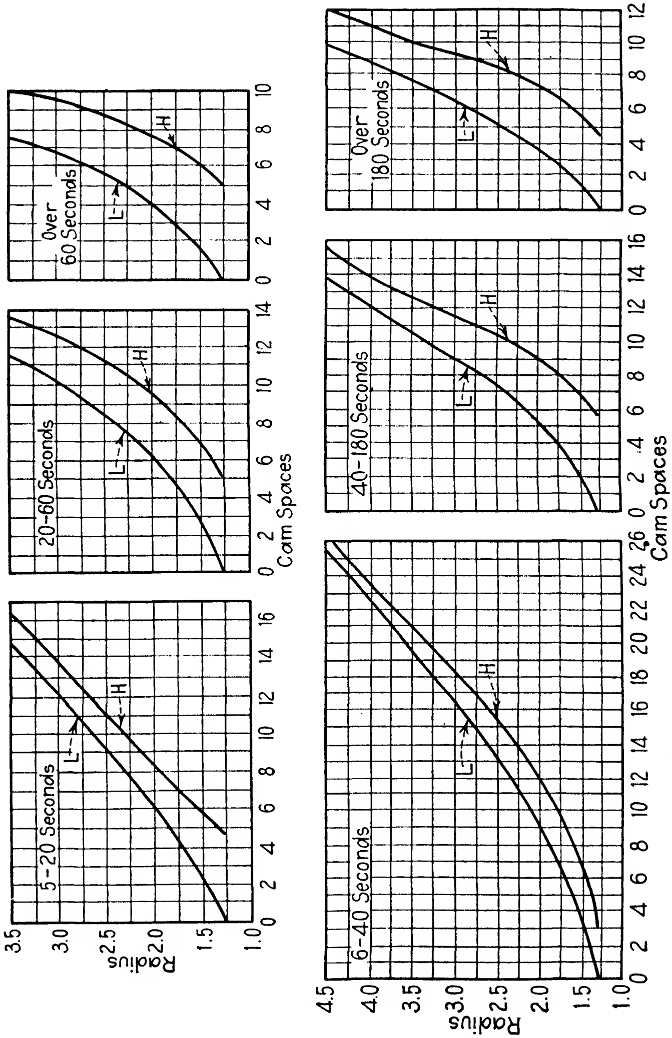


FIG. 145.—Pull-out charts for 5 to over 180 seconds.

Plates for cams are best made of cold-rolled steel. The steel should be annealed before laying out the cams, so as to eliminate the strains caused by rolling. After finishing, the cams should be boiled in potassium cyanide at a temperature of 1600°F.

for 20 min. and then quenched in a good, thin heat-absorbing oil. In quenching, the cams should be held edgewise to prevent distortion.

Since movements of the cross slide must synchronize with those of the turret, it follows that the cross-slide cams must be

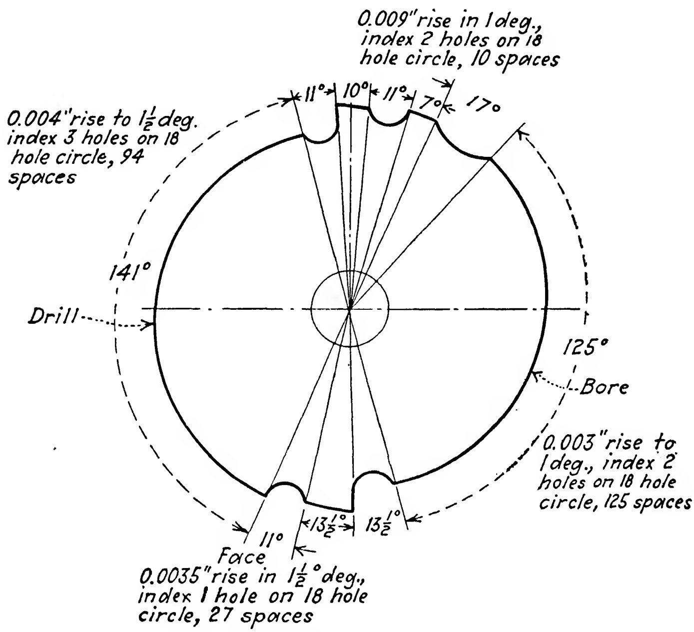


FIG. 146.—Example of cam layout.

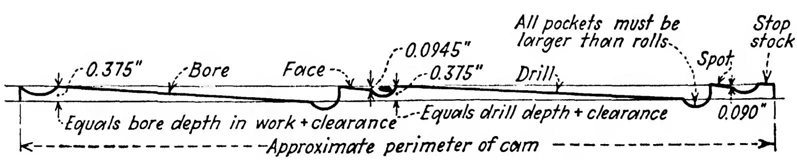


FIG. 147.—The same cam in a straight-line layout.

made so that the work will be formed and cut off in the same time that the turret makes a complete turn. Cross-slide cams hardly ever need replacing, since they can be set in various positions on the cam-shaft in relation to the extreme rise of the forming or the cutting-off lobes, anchor-pin holes being provided for the purpose.

In laying out a turret cam, the layout should first be made full size on paper to determine the rises and degrees of travel of the various lobes for the operations to be performed. The rises for the major lobes, as for drilling, reaming, boring, and tapping, are determined by the depth the various tools must enter the work, adding a small amount to insure that the tools will not immediately ram into the work but will make contact gradually. The layout of the lobes for the minor operations, such as stock stop, spotting or facing is made after all major operations have been settled upon. If a case arises where the

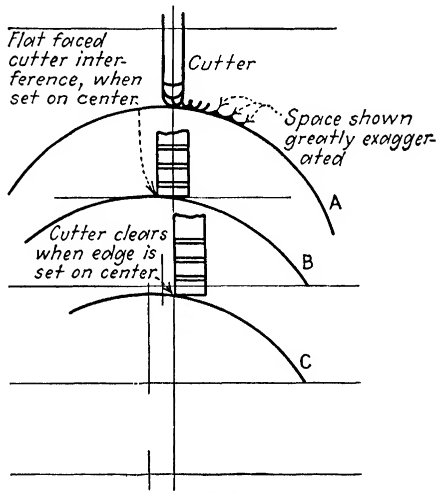


Fig. 148.—Milling the cam surface.

major operations have been given too much room, they may have to be revamped so that the minor operations can be worked in.

Threading Lobes on Screw-machine Cams.—Taps and dies for automatic screw machines are mounted in a block that slides in a positive holder, with a coiled tension spring attached behind the block. This arrangement allows the cutter to advance slightly ahead of its holder by pulling on the spring while being led by the revolving work. The holder is positively secured in the turret and is advanced slightly behind, but following the threading tool, by a lobe on the lead cam. This precaution prevents the cam from crowding the cut and spoiling the work.

Actual practice has determined this cutter advance to be

12.5 per cent ahead of the corresponding cam rise. This allowance is easy to obtain when designing the cam lobe, by using a rise for a thread which has a lead 12.5 per cent, or 1/8, less than the thread lead on the work. The procedure for the lobe design is simple and involves no tedious graphical layouts.

An example would be cutting 32 threads per inch for a distance of 3/4 in. Take the thread lead or 0.031 in. and deduct from it 12.5 per cent or 0.004 in., which leaves, 0.027 in. This latter lead is used when computing the cam rise. Since the number of spindle revolutions for threading with the lobe are the same as the number of threads to be cut, plus 4 (four revolutions added to clear the work when approaching and leaving) and the number of revolutions required are determined by dividing the travel by the feed per revolution, we compute as follows: Dividing 0.750 in. by 0.027 in., gives 28 revolutions, and adding 4 gives 32 spindle revolutions, for threading with the cam lobe. It is obvious that, while the tap or die is being led to cut a distance of 0.031 in. at each revolution of the work, the tool holder normally travels but 0.027 in.

The height of the cam throw must be 10 per cent less than the length to be threaded. In our example, we must include the four extra revolutions, so the length becomes 7/8 in. Next deduct 10 per cent and the required throw is 0.788, or approximately 25/32 in. This computation favorably changes the toolholder travel from the normal figure 0.027 to 0.025 in. per revolution.

The standard Brown and Sharpe No. 00 automatics have no back rod by which spindle speeds can be controlled in the overhead works. The No. 0 and No. 2 machines have these back rods, and when not used for changes from maximum to minimum speeds, the threading lobes for all three machines are similarly designed.

The contour of the rise on threading lobes can be a spiral, similar to that used on regular cam rises. Some threading lobes, however, have a lead in one turn so great, that spiral rises are impractical to make. Spiral rises can be used on threading lobes if we have based the rise, the throw, and contour design on the foregoing methods. The follower roll necessarily assumes a gradually increasing clearance relative to the lobe when using a spiral rise.

When impossible to use a spiral rise, substitute the arc of a circle, scribed with a radius equal to the distance from the highest point of the lobe, to the center of the cam, and then deduct 10 per cent.

For the number of revolutions in the layout for threading on, when a back-rod shift is not used, divide the fast spindle speed by the slow; then multiply the quotient by the number of revolutions for threading off.

When threading on the No. 0 and No. 2 automatics, it often occurs that the fast spindle speed is the highest given in the column on the belting diagram, yet gives the correct number of surface feet per minute for the machining operations. The next lower, or the intermediate, speed is too fast for threading, while the lowest speed in the column is the one desired. In such cases the back rod on the machine is resorted to for shifting belts in the overhead works from high speed, passing the intermediate speed, and obtaining the lowest revolutions per minute.

This change has a direct influence in computing the threading-off lobe. It does not affect any of the foregoing rules for obtaining the rise and throw, or for determining the number of revolutions on, in the layout, or the methods for obtaining the lobe contours.

What happens is that just previous to threading on, the back rod shifts the belts from fast to slow speed with the same results as previously described, but when the follower roll is above the highest point on the cam lobe, and the threading is finished, the spindle is reversed by its friction clutch, instead of using the back-rod shift, and threading off is accomplished at the intermediate speed. Therefore the number of revolutions for threading off, in the layout, are determined by dividing the fast speed by the intermediate speed, and multiplying the quotient by the number of revolutions for threading on.

Formulas for Calculating Threading Lobes When Back Rod Is Used

Let F = revolutions per minute of fast speed.
S = revolutions per minute of slow speed.
I = revolutions per minute of intermediate speed.
R = revolutions—threading off.
r = revolutions—threading on.
N = number threads to be cut plus 4, lead reduced 12.5 per cent.

Then

$$R = \frac{F}{I} \times N$$

$$r = \frac{F}{S} \times R$$

If T = cam throw,

n = number of threads on the work,

and

L = lead of threads on work.

Then

$$T = L(n + 4) - 10 \text{ per cent.}$$

Precision Work on the Automatic Screw Machine.—One of the small but important parts common to mechanical refrigerators is the valve needle. While varying in individual design, all makes require that the conical point be accurately ground, for both angle and surface, in order to provide a perfect seal when in contact with the valve seat.

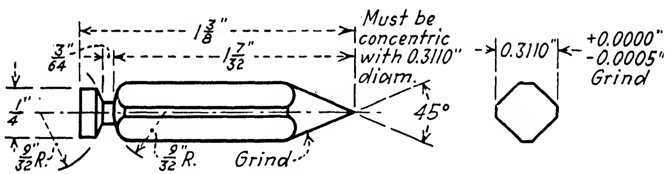


FIG. 149.—Needle valve for refrigerator.

Figure 149 shows a representative valve needle requiring an interesting sequence of operations. This part is made from ¼-in. square stainless steel. A double-ended blank suitable for making two valve needles is produced upon a No. 2G Brown and Sharpe automatic. Tooling for this operation is shown in Fig. 150. It includes an angular cutting-off tool held in a turret position and operated by a fixed guide on the front cross slide, in order to produce a clean-cut, sharp point on the cut-off end of the blank. The production rate is 36 blanks per hour, equivalent to 72 valve needles per hour.

After the blanks are hardened, the first grinding operation is performed on a No. 11 Brown and Sharpe plain grinder, producing the 0.3110-in. diameter and removing 0.042 in. of stock. Auto-

matic screw machines are employed in making many of the smaller parts used in refrigerator units.

Figures 151 and 152 represent the blank of a valve seat produced in two operations. The part is made from Tobin bronze bar stock upon a No. 2G automatic screw machine, as

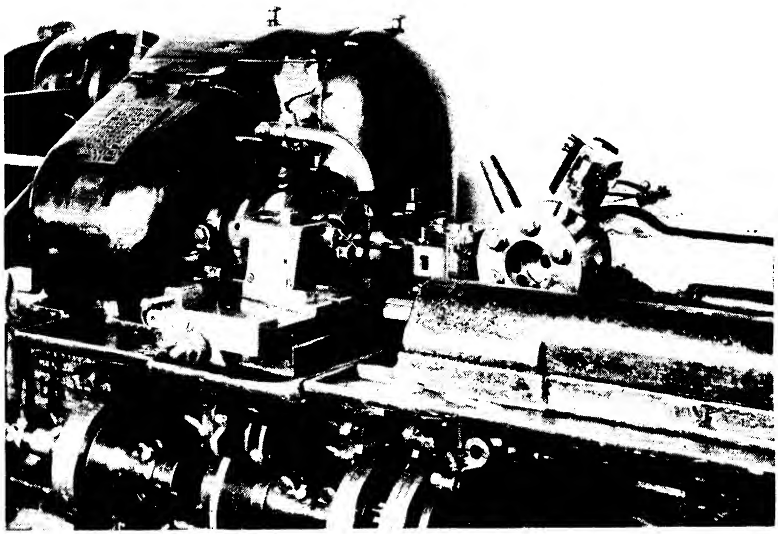


Fig. 150.—Tool set-up for needle valves.

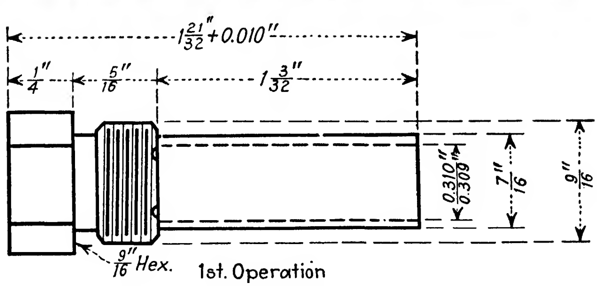


Fig. 151.—First operation on valve seat.

shown in Fig. 150, at the rate of 114 pieces per hour. The operations of drilling and threading the cutoff end of the piece, shown in Fig. 151, are performed on a No. 0G automatic equipped with the chute magazine shown in Fig. 153. This magazine automatically inserts pieces into the chuck. The production rate is 205 pieces per hour.

Figure 154 is a pipe connection coupling nut made from ⅝-in. hexagon brass rod. Because of the high rate of production obtainable upon such parts the automatic rod magazine is

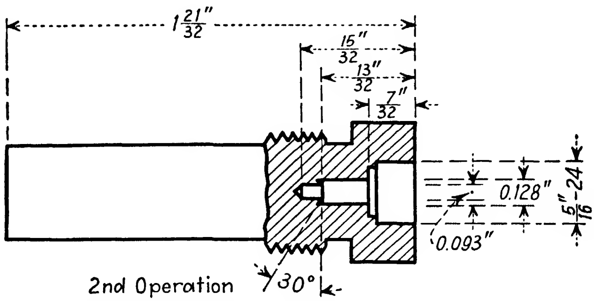


FIG. 152.—Counterboring in second operation.

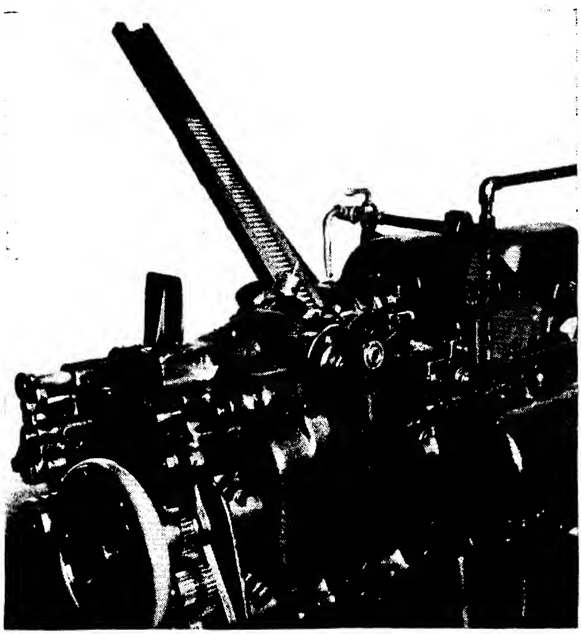


FIG. 153.—Magazine feed for second operation.

again used to advantage. A No. 2 automatic produces this part at the rate of 864 pieces per hour.

The grade of material from which a part is made materially influences production possibilities. All production rates given

above are based upon the material from which these parts were made, and it should be possible to increase production upon some of the screw-machine parts if slightly freer cutting materials should be used. It must also be remembered that one man can operate a number of automatic screw machines upon work of the above nature.

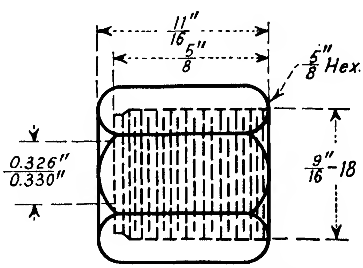


FIG. 154.—Small coupling nut.

Making Small Shaft on the Multispindle Automatic.—The $2\frac{1}{2}$-in.-long automobile windshield-wiper shaft in Fig. 155 is made on a $\frac{9}{16}$-in. capacity five-spindle National Acme machine capable of producing about 600 pieces per hour. Since the machine had an antifriction spindle bearing, an ingenious arrangement for stopping the work spindles in any or all positions was accomplished by using the disk clutches on the work spindles at the rear of the front spindle bearings. These clutches are actuated by a stationary cam attached to the

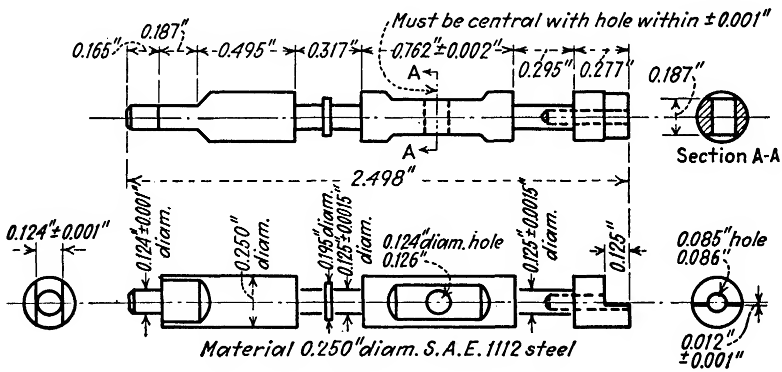


FIG. 155.—Shaft for windshield wiper.

inside of the head-stock section of the machine. As the work-spindle carrier is indexed, the spindles are stopped as required. Whenever a cross-drilling or cross-milling operation is performed, the work spindle must be stopped.

By combining most of the operations on the first three positions or stations it was possible practically to finish the shaft before forming the 0.124-in. diameter. In this way the stock was not

weakened and more production could be obtained by using greater feeds.

The sequence of operations (Fig. 156) and the tooling used are as follows, starting in the first position, that is, the lower front station (Fig. 157):

1. The three 0.125-in. diameters and the 0.195-in. diameter are formed with a dovetail forming tool while the work is supported in a ball-bearing rest located on the tool slide. The 0.085- to 0.086-in. hole is also centered and the part faced to length with a combination spotting and facing tool carried in a rotating high-speed drilling attachment.

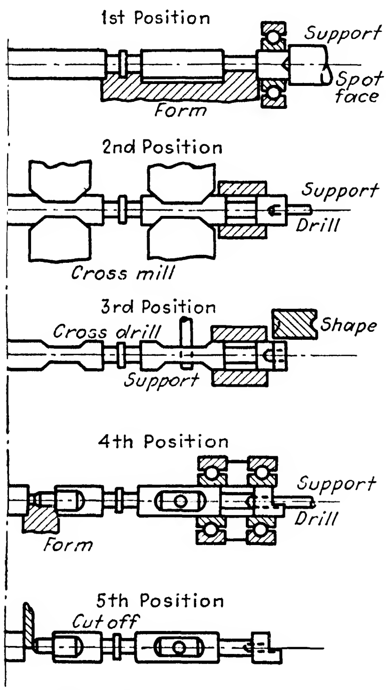


FIG. 156.—Sequence of operations on shaft.

2. The work-spindle carrier indexes the work to the second position where the spindle is stopped while the cross-milling attachment, held in a special side slide, feeds across the work. The two sets of butt mills mill the four flat portions with the 45-deg. angles at their ends. This attachment is independently motor-driven through the cable shown in the illustration. While the milling is being accomplished, the work is supported from the tool slide and the 0.085- to 0.086-in. hole is drilled halfway with a rotating high-speed drilling attachment.

3. The work-spindle carrier, advancing the work to the third position, keeps the work spindle stopped and locked in position for drilling the 0.124- to 0.126-in. hole, at right angles to the central milled flats. This cross-drilling attachment is also driven direct with a small motor and is advanced by a cam on the rear cross-slide cam disk. In this same station a support is used on the tool slide and a special shaping attachment mounted on the

tool slide shapes the 0.125-in. section off 0.012-in. below center. This type of attachment was used because a square shoulder at the termination of the shaped section was required. The attachment carries a tool similar to that used on a shaper and is actuated across the work by a rotating cam while being advanced into the work longitudinally by the tool-slide cam.

4. As the carrier indexes to the fourth position the work spindle is unlocked and starts to rotate for forming the 0.124-in. diameter.

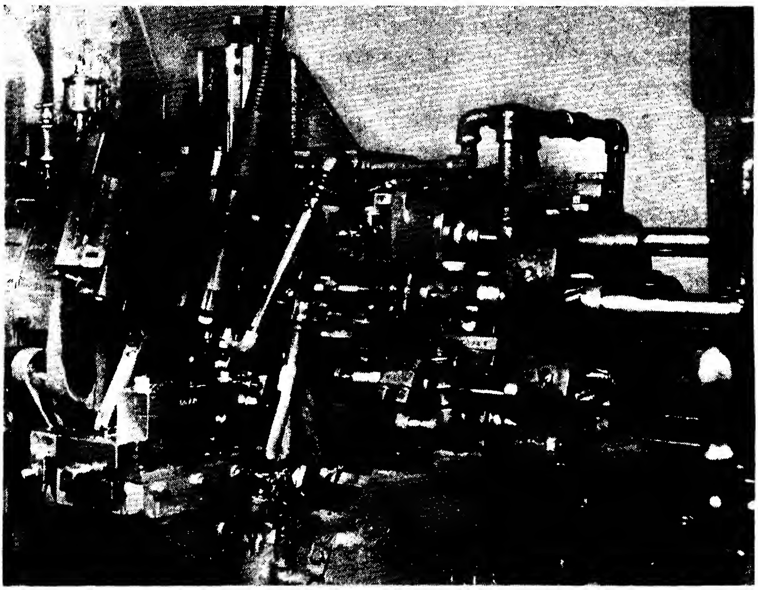


FIG. 157.—Machine tooled for windshield wiper shafts.

eter. A flat-type forming tool is held in a tool post mounted on the rear cross slide. A double ball-bearing support is used on the tool slide to steady the work for drilling the other half of the 0.085- to 0.086-in. hole. This drilling is again accomplished with a rotating high-speed attachment. The high-speed drilling attachments used in the first, second, and third positions and the special shaping attachment are driven directly from the standard center-idler drive gear shown in the illustration just behind the center main-frame section. This idler gear is in turn driven from the gear-box section of the machine through a shaft located in the second position.

5. The fifth position is used for cutting off the work and feeding out the stock for the succeeding piece. The stock stop is shown in the illustration in the retarded position ready for the tools to advance to the work.

Cutting Life of Tools on Brass.—There are a number of factors which may affect the cutting life of forming tools, drills, cut-off tools, and other screw-machine tools. Among them are the nature of the stock to be machined, the character of lubrication or cooling of material and cutting edges, and on some kinds of work the rate of feed and speed of work past the cutting tool. Certain conceptions of the effects produced in working free-cutting brass in respect especially to depth of chip and surface speed of work are not borne out by extensive experiments conducted on this material in the automatic screw machine.

One of the most thorough studies* of this subject has led the investigators to some conclusions of unusual importance, drawn from examination of data they have compiled on life of tools after each grind. The data covered among other values, the total cutting *time* the tools lasted before regrinding, the total cutting *depth*, and the *linear distance* of cutting in feet—which meant the average cutting speed in feet per minute times the cutting time per grind.

Examination of the values for "linear distance of cutting" leads one to wonder if the lapping action on the edge of the tool might not be the determining factor in form cutting on free-cutting brass, modified, of course, by the character of the finish wanted. In the range of the tests made the average cutting speeds were varied by a more than 5-to-1 ratio from the largest value to the smallest and the feeds per revolution varied through a 15-to-1 range, yet the linear distance of cutting, using high-speed tools, came within a 2½-to-1 range, and this variation could be accounted for by the difference in the desired finish. The tests cover tools with ground forms, perhaps more resistant to the lapping action of the work than tools that are finish-formed and then hardened.

It appears that with ground-form tools at least, operating on free cutting brass, the principal factor in the life between grindings is the linear distance through which the edge of the tool

*** Based upon studies made by L. D. Spence and J. A. Hall as recorded in their report to the A.S.M.E.**

contacts with the work. If this is correct, the conclusion is drawn that maximum production rate and greatest production between grinds will be secured by maximum possible feed (limited by driving power and ability of the stock to withstand deflection under pressure from a partly worn tool) and high cutting speed. Speed increase beyond a certain point may perhaps result in loss, but the limiting rate had not been reached in performing these tests at 600 ft. per minute.

There was formerly a belief that carbon steel was to be preferred to high-speed steels for form tools if fine finish was required on the work. The tests bring out the fact that high-speed steel tools have longer life in forming operations, the advantage here being perhaps more conspicuous than with cutting-off tools.

Drilling tests with high-speed drills in the automatic have led to an apparent conclusion that on free-cutting brass, feeds greater than commonly employed can be used and high-cutting speeds do not cause undue increase in wear.

Section IV

BORING MACHINES

CHAPTER XVIII

BORING MACHINES

There are now four types of boring machines. The best known are the two kinds of horizontal boring machines, floor and table types, and the vertical machine, commonly known as a boring mill. A more recent development is the "single-point" boring machine, sometimes known as "diamond" boring machine. This type was so named because originally it used diamond-tipped boring tools, nearly always on such nonferrous metals as brass, aluminum, or the babbitt type of bearing metals. Using a single cutting edge or point, and removing but a few thousandths of metal, these tools produce very accurate holes with excellent surfaces.

With the coming of tungsten- and tantalum-carbide as a cutting material, the use of this type of machine has grown, especially in comparatively small work. The name "diamond" boring still clings in spite of the use of other cutting tools. This type of machine is no longer confined to small holes but is being adapted to such work as cylinder bores in automobile cylinder blocks. Owing to the increased use of cutting tools that are not diamonds, the term "single point" should be used to designate the type of machine designed especially to use a single-point cutting tool.

All horizontal boring machines use boring bars which revolve in the work. They also use milling cutters and drills. But the work is always stationary. In the vertical boring mill the work revolves and the tools are stationary as in the lathe. In fact, the vertical boring mill closely resembles a lathe with its head on the floor and its bed vertical. When a side head is added, as is becoming quite common, the similarity is greatly increased, as the side head does the work of a lathe carriage.

The main difference between the floor and table types of horizontal boring machines is in the size. For large work the machine is built with a base or floor plate, usually level with the floor of the shop. The work is fastened to the floor plate and

bored, drilled, or milled by tools carried in a bar that can be moved both vertically and horizontally. The bar is carried in a head which can be moved up and down on the column and which feeds the bar into the work.

TABLE-TYPE MACHINES

Table-type machines were originally made in comparatively small sizes, with the boring spindles in a stationary head. Holes were located by moving the worktable both vertically and horizontally. This type of machine has been replaced by the Lucas type, which, as with the floor type, has the boring bar mounted on a column on which it moves vertically. Cross movement is, however, obtained by moving the work table, instead of the

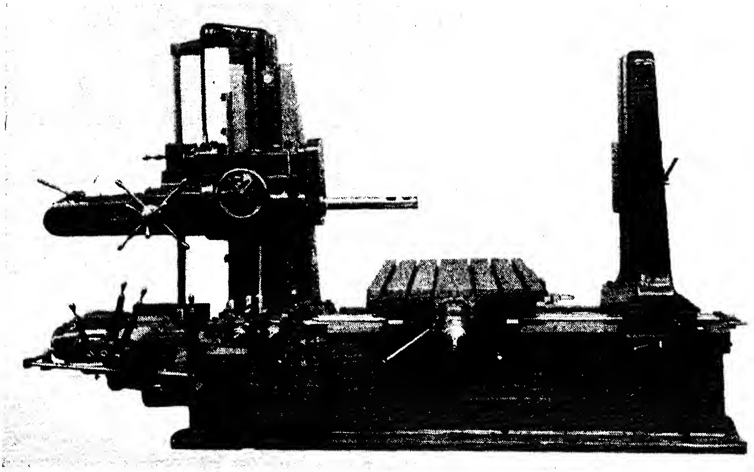


Fig. 1.—Lucas horizontal boring machine.

column as in the floor machine. Boring machines of this type are now made in much larger sizes than formerly, some of them having boring bars 5 in. in diameter. Machines of this type can handle a large variety of work, from accurately locating and boring holes in jigs and fixtures, to small-lot manufacturing of such machine parts as cylinders, bed plates, brackets of various kinds. In contract or jobbing shops, they are especially useful on many jobs, and railroad shops use them to advantage. Examples of this type of machine follow:

Lucas Boring Machine.—In Fig. 1 is a medium-size machine built by Lucas Machine Company. All controls are centralized at the left, as in the engine lathe. It has power movements and quick returns in all directions, micrometer dials, dial gages on column and table, and all the conveniences for either shop or toolroom work. One of the uses of these gages is shown in Fig. 2:

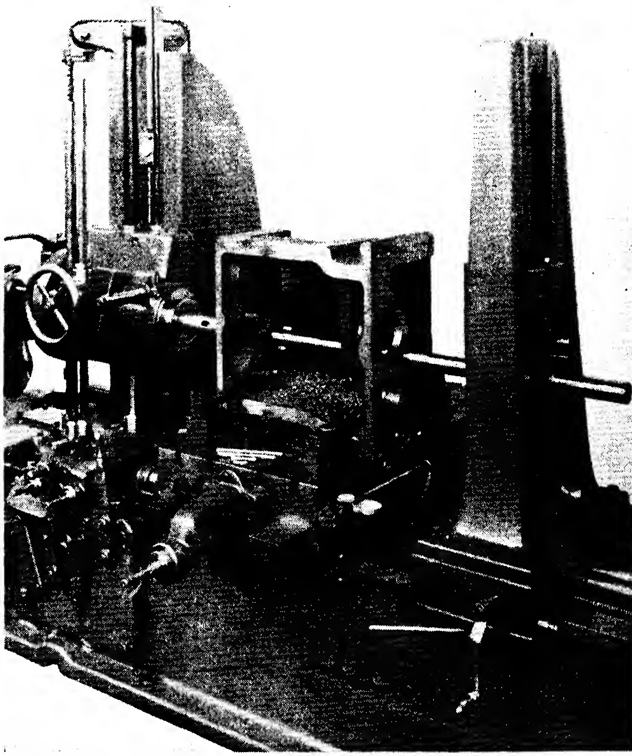


Fig. 2.—Where dial gages aid in accurate boring.

accurate boring is being done at specified center distances. Standard distance rods or bars are used in connection with the dial gages to check the position of the work and bar in both vertical and horizontal movements. These rods can be seen in place on the column and at the side of the table. Other standard rods are seen lying on the front of the table.

Two regular shop jobs are shown in Fig. 3. One is a plain boring job but on an awkward piece of work. This is a case where

this type of machine is much more convenient than the lathe. The other example is also one that is hard enough to hold on any

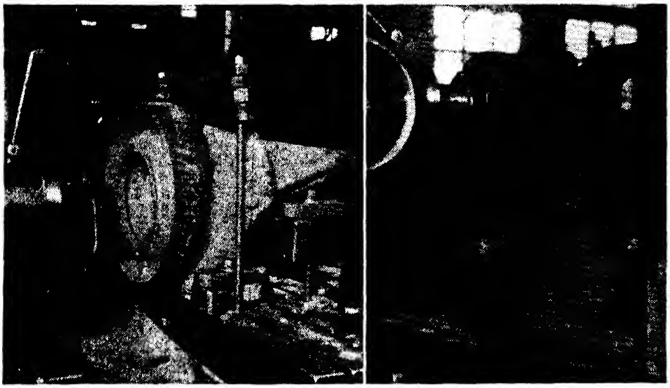


FIG. 3.—Two awkward jobs for the boring machine.

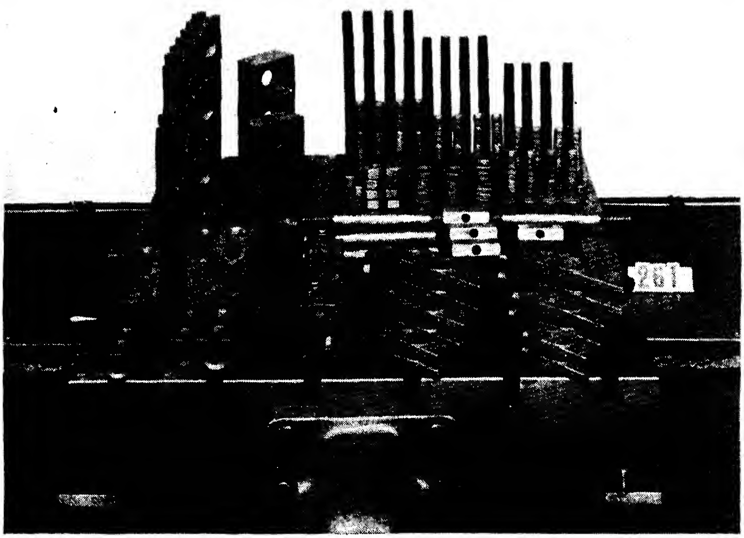


FIG. 4.—Lucas set of boring machine "furniture."

machine; it is being faced by a sweep cutter. The tool is fed across the work by the old star-feed method, in which the toothed or star wheel on the end of the feed screw strikes the projecting

pin as it comes around and the feed screw is turned part of a revolution.

Figure 4 shows a collection of blocks, clamps, and bolts that are very convenient in holding any kind of work on either a boring machine or planer table. A study of these blocks, some with tongues that fit the T slots, some with clamping screws, and others with steps of various sizes, will be well worth while. It pays any shop to have enough clamping "furniture" in a convenient place. It saves a lot of time in setting up work on the machine.

A drill speeder is a very convenient accessory for a horizontal boring machine. For, although most of the work may be of fairly large size, there are frequently a few small holes to be drilled. These can be drilled more accurately while the work is still in position on the boring machine; also, one saves time in handling the work. A drill speeder, as shown in Fig. 5, increases the spindle speed, through a gear train inside the case. This drives the drill at its proper speed and saves much time and trouble.

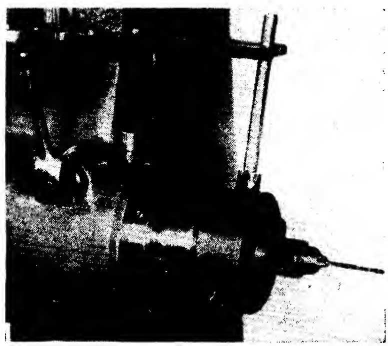


FIG. 5.—Drill speeder for small holes.

Giddings and Lewis Machine.—Another machine of this type is made by the Giddings and Lewis Machine Tool Company. In this case the head is at the right. The machine shown is of large size and has a secondary or auxiliary spindle for lighter work, as shown in Fig. 6. This handles much the same types of work as has already been shown, but the machine is of larger size. The heavy boring job in Fig. 7 is held in a heavy fixture which can be turned 90 deg. for boring the holes at the end. A milling job is being done in Fig. 8, the work being held square by the angle plate behind it and supported by the jacks under the front portion.

Boring machines of the table type have made such a place for themselves in the modern shop, and are so well known that their operation requires but little detailed instruction. The usual

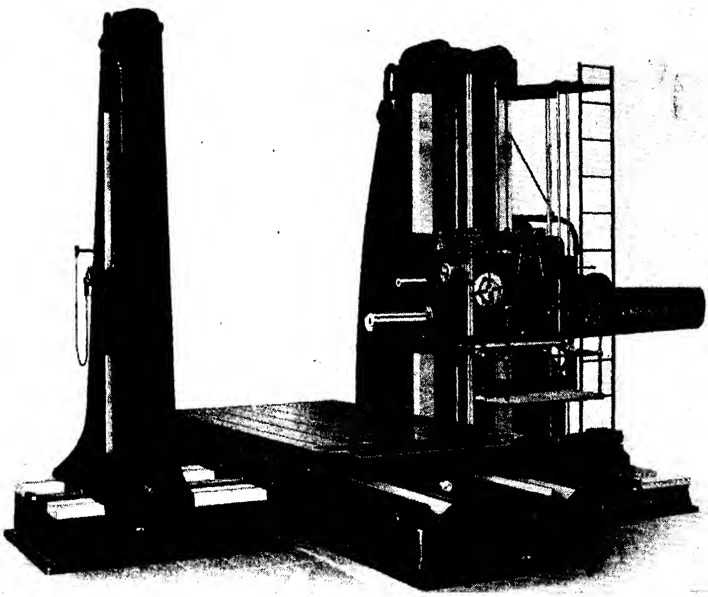


Fig. 6.—Giddings and Lewis boring machine.

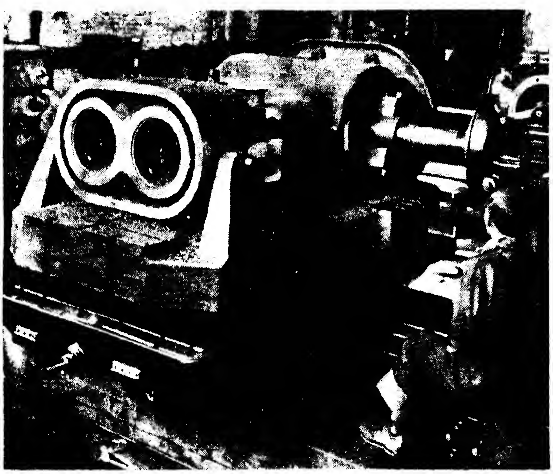


Fig. 7.—Heavy boring job on Giddings and Lewis machine.

methods of locating work, and of holding it without springing, proper cutting speeds and feeds, enable any shop to secure rapid and accurate work. They are standard equipment in nearly all shops.

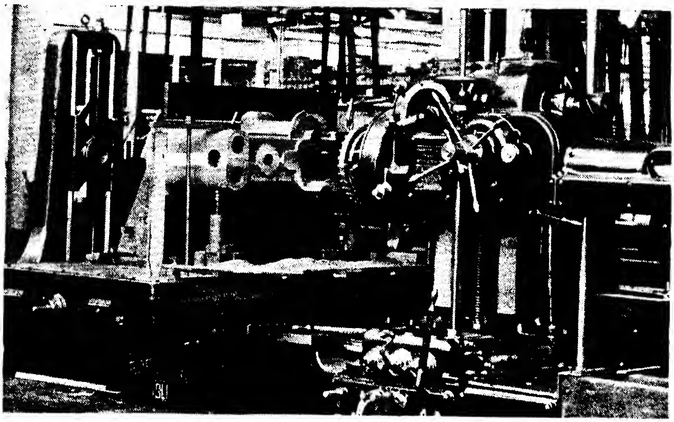


FIG. 8.—Milling on machines of this type.

VERTICAL BORING MILLS

In general shop language the term "boring mill" refers to a vertical machine, to distinguish it from a horizontal machine. Small boring mills, or those used for a few simple operations, are sometimes called chucking machines. This type of machine dates back to the early days of machine tools. It consists of a horizontal table, driven by a vertical spindle. The tools are carried in a ram that has a vertical movement and which can be positioned at different points along a cross rail that supports it over the table. The cross rail moves vertically on the housing. The ram can usually be swung to an angle for boring taper holes. Sometimes the ram carries a turret for boring or turning. Many boring mills carry two heads on the cross rail; frequently one has a turret and the other a ram on a swivel base.

As many boring mills now have side heads, and as general operations are similar in both cases this type of machine will be illustrated by one with a side head.

Safety Ladder for Large Work.—It is not always easy to measure high work that is on a boring-mill table, even when the machine has been stopped. And even then there is a chance of

injury in climbing on the machine itself, not to mention the possible marking of either paint or machine finish. The safety ladder (Fig. 9) was devised and built in the shops of the General Electric Company at Pittsfield, Mass. The ladder has four hooks that fit into straps or eyes fastened to the base. The four fastenings hold the ladder firmly and enable the operator to reach

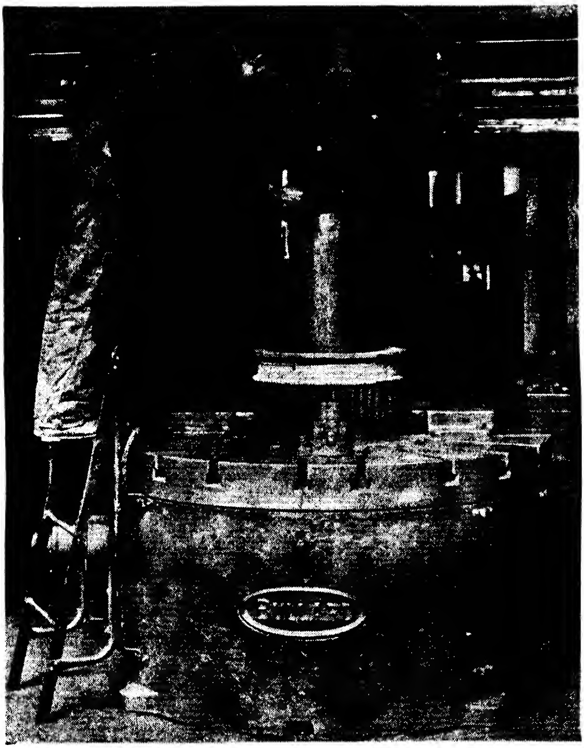


Fig. 9.—Safety ladder for boring mills.

any work the machine can handle. It will also be noticed that there is a toe guard on the step just above the table to prevent possible injury when the table is in motion.

Vertical Turret Lathe.—The term "vertical turret lathe" originated with the Bullard Company when they put a side head on their vertical boring mill. With this side head the machine can perform practically any chuck or faceplate work that can be done on a lathe equipped with a turret instead of the tailstock.

There is the added convenience of chucking or fastening work, owing to the table being horizontal. This makes it necessary only to lay the work on the table, adjust it to position and fasten it; on the lathe it must be supported by hand or by a crane while it is being located and fastened.

As can be seen in Fig. 10, both the turret and the side head have two motions. The saddle carrying the turret can move on

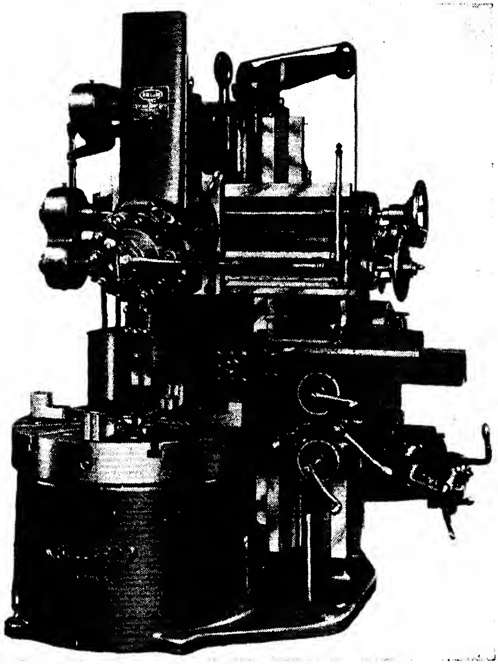


FIG. 10.—Bullard side-head machine.

the cross rail and the turret slide has a vertical motion. Both are power movements and include both feeding and quick traverse, the latter for setting up, approaching the work, and returning after a cut. Similarly the side head has both vertical and cross movements for the same purposes. The vertical turret has five positions and there is a four-tool turret on the cross slide. The value of all these features will be seen in the operation outlined in Fig. 11. All operating controls, changes of speeds and feeds, are centralized so as to be within easy reach of the operator.

Instead of automatic feed trips, so-called observation stops are provided. These are adjustably mounted on graduated scales and micrometer dials and aid in securing duplication of various sizes.

Typical Work for Vertical Machines.—Two interesting jobs are shown in Figs. 11 and 12. In Fig. 11 all five holes in

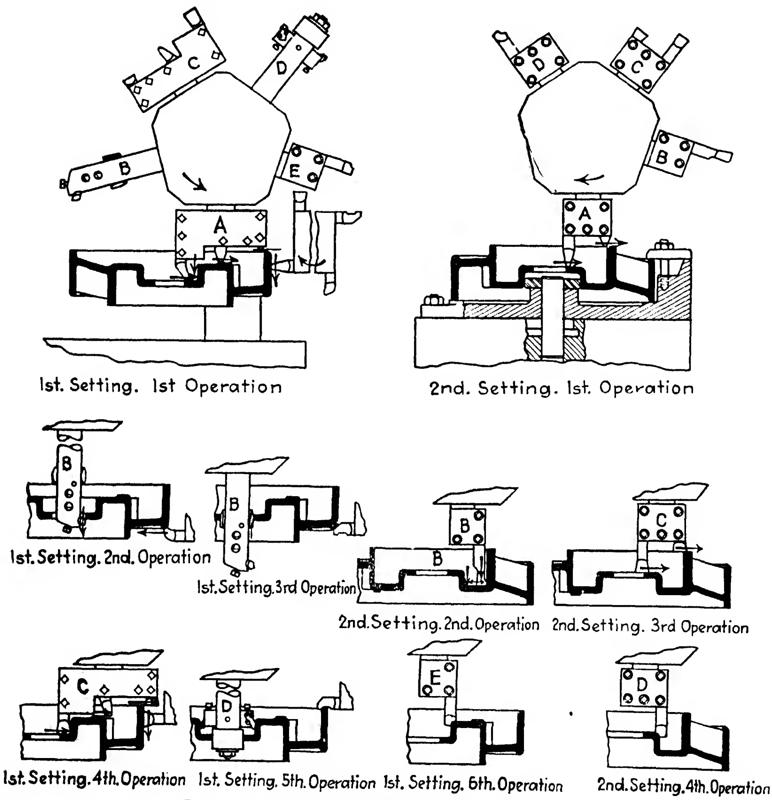


FIG. 11.—Tool layout for Bullard machine.

the turret are used. In the first operation of the first setting the three tools at A face three surfaces at different heights. Then the front cutter in bar B bores the center hole and the second cutter finishes it in the third operation. Tool C finishes the three faces previously roughed out, while tool D bores the large recess, the boring head being guided by the pilot in the hole

previously bored. The last tool *E* chamfers the corner in the sixth operation. The work done by the four tools in the side head can be easily followed in the different operations. Opposite edges on the same tool chamfer the lower corner in the third operations and the upper corners in operation five.

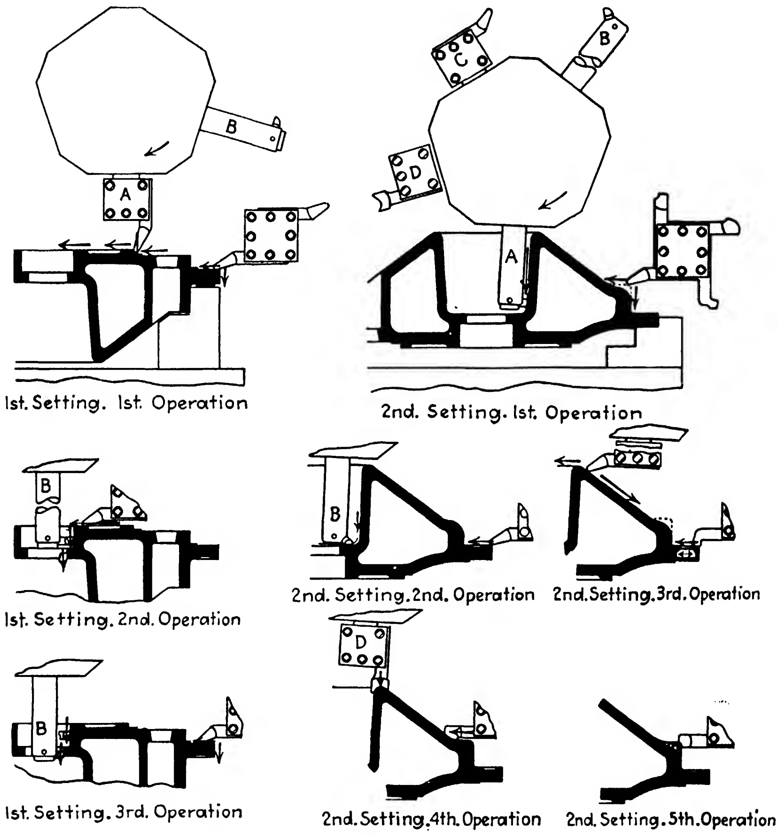


FIG. 12.—Another typical tool layout.

Reversing the work, as in the second setting, all remaining operations are done with the four turret tools in the order shown, the direction of turret rotation being reversed in this case. Two surfaces are rough faced by tool *A*, the recess faced and chamfered by *B*, both surfaces finished by *C*, and the inner corner rounded by *D*. The small arrows show the direction of the tool movements.

In Fig. 12 is shown another typical job that is handled to advantage on a machine of this type. This is a special cylinder head. The operations can be easily followed by noting the tool designations and the small arrows showing the direction of the tool movements. The boring bar has two cutters, one for each diameter.

In the first operation of the second setting the turret slide is swiveled on the saddle to secure the proper angle. In the third operation the outside angular cut is made by using both the

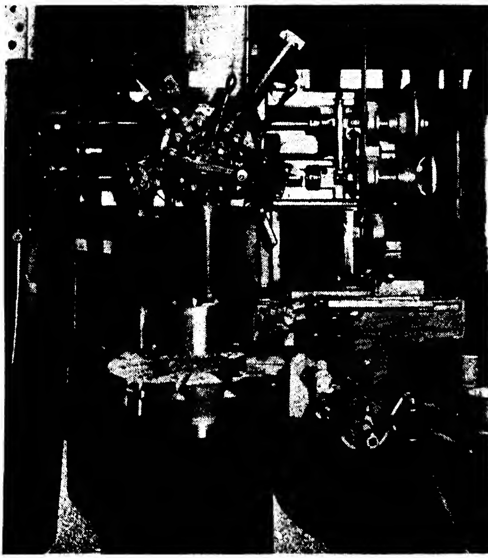


Fig. 13. Fig. 14.

Fig. 13.—Turning and boring a bushing.
Fig. 14.—Turning a large crown brass.

main-head cross feed and a compound gear connection with the vertical feed.

These machines are made in a number of sizes, from 24- to 86-in. capacity. Some of the larger sizes have a side head on each side of the machine and two heads on the cross rail. Boring mills with side heads are now made by several machine-tool builders.

Railroad Jobs.—Two railroad operations on the boring mill are seen in Figs. 13 and 14. Figure 14 is the turning of the

outside of a crown brass that is held on a central fixture on the machine table. The work can be easily located by circles on the base of the fixture and clamped in position by the screws in the upper plate. After being located in position, it becomes a regular turning job, the side head being used for feeding the tool down the work.

A combination boring and turning operation is seen in Fig. 13. This is a floating bushing for a locomotive side rod, which is finished inside and out. The hole is bored by the bar in the turret while the tools in the side head first turn the outside to size and then cut the piece off to length. As shown, the cutting off tools are ready to complete the operation.

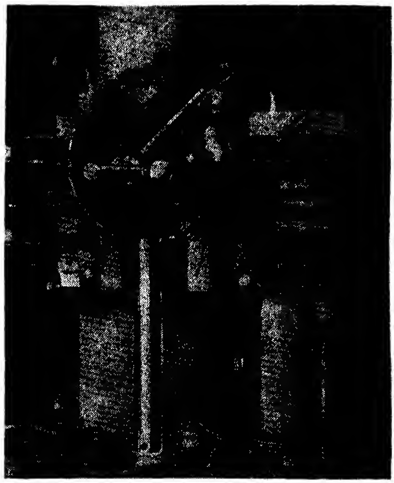


Fig. 15.—Method of testing turret accuracy.

Testing Turret Accuracy. The illustration (Fig. 15) shows how the accuracy of the indexing of a turret on a boring mill can be easily tested. In this case the bar extends 20 in. from the turret face and the point of contact with the indicator over 27 in. from the center of the turret. The test bar is put in one hole after the other and checked in the vertical, or working position. Turrets in turret lathes or on other machinery can be tested in the same way.

THE MULT-AU-MATIC METHOD

Designed primarily to meet the demand of automobile makers for greater production of many parts originally made on the engine lathe, the Bullard Mult-Au-Matic has made a place for itself in many kinds of manufacturing. It covers a wide range of work in which boring, turning, facing, drilling, reaming, grooving, or threading is required.

As can be seen in Fig. 16, it is essentially a vertical automatic lathe, usually with from four to eight work spindles and carrying from three to seven tool heads. Sizes run from 6 to 20 in.

One spindle is always at the loading position, except during the indexing; where necessary, double indexing, with two loading stations, can easily be arranged. The tool heads remain stationary on the central column, except for their functional movements. The work-spindle carrier indexes the spindles under each successive tool head, all operations being performed simultaneously, but on separate pieces of work.

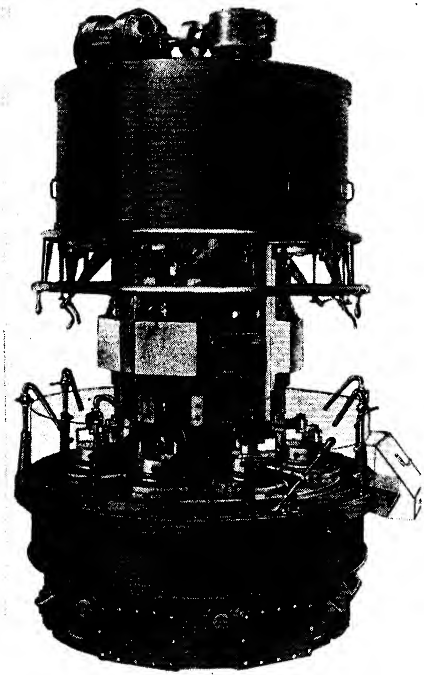


Fig. 16.—The Bullard Mult-Au-Matic.

Characteristic Features.—Summed up briefly the characteristics of the six-spindle machine are:

Six work-holding spindles.
Five universal tool-carrying heads.
Widely variable and independent spindle speeds at each station.
Independent and widely variable feeds for each tool head.
Simplicity of equipment.
Elimination of sweep cutters.
Independence of tool setting.
Accurate, positive feed stops.

Accurate indexing of spindle carrier.

Independent adjustment of spindles in carrier with relation to each other and to registry mechanism.

Automatic operation.

Positive coordination and interlocking of all machine movements.

Mechanically controlled rate of production.

Continuous flow lubrication of all bearings and gears.

Filtration of all lubricating oil as circulated.

Vertical construction.

Minimum floor space.

The cylindrical base forms a rigid surface plate to insure accuracy in alignment. It is divided into two sections, one serving as a reservoir of lubricating oil that is forced to every bearing, the other containing an ample supply of coolant. Both have independent power circulating pumps.

The work spindles are carried in a heavy turret that revolves about the control column at its base. Each spindle is given its proper rotating speed for the work done at each station. This is done automatically as it comes in position under the work head. The spindles are stationary at the loading station and during indexing. The indexing is done at a constant speed and automatically, after the tools have withdrawn from the various cuts.

The control drums, work turrets, indexing mechanism, master registry pin, and the turret binder are all inside the column. They can be easily inspected and adjusted by removing a cover plate at the loading station. The tool-carrying heads are mounted on the faces of the central column, at the various work stations. Each head is independent in direction, amount, and rate of its movement. The heads are gibbed to the column and are made both standard and double-purpose. The standard head has one movement, vertical, angular, or horizontal. The double-purpose head has two slides, one for vertical and the other for horizontal movement. Any head can be geared for thread cutting, but this is not done on average work.

The sequence of the operating functions gives a good idea of the way in which the machine operates. These, in connection with some of the details of the operations, which follow, show why the machining time on these machines is so low.

Sequence of Operative Functions:

1. Power is applied to main-drive shaft which, by direct connection and at constant speed, immediately and continuously actuates:

a. The lubricating-oil circulating pump located in open section of machine base, which forces oil to filter and reservoir, from which it flows by gravity to all parts of the machine.

b. The cutting compound pump located in closed section of machine base.

c. The control-clutch gear, within the column, through which all automatic functions are timed and actuated.

2. By manual engagement of main operating clutch, power is applied to work-spindle driving mechanism.

3. Control drum is released by manual disengagement of index safety lock located on column face at loading station.

Then, automatically, within 3 sec., required for one complete revolution of the control shaft:

4. Control drum is advanced, engaging control-clutch ring with indexing mechanism.

5. Drive clutch is disengaged, the automatic brake is applied, bringing spindles to rest.

6. Carrier binder is released and master registry pin withdrawn.

7. Carrier is advanced one station by indexing mechanism—driving pinions and work-spindle gears automatically disengaged and re-engaged by advancement of carrier.

8. Master registry pin engaged; carrier binder operated, index complete.

9. Drive clutch engaged, applying power to work spindles and feed works; simultaneously engaging the rapid advance motion in feed works. Control drum and shaft brought to rest and locked.

10. Tool heads rapidly advanced to point where cutting feed should begin. (This point selective and adjustable for each head.)

11. Rapid advance disengaged and feed engaged by trip dog adjustably mounted on feed-control disk, which is directly driven by feed drum on each head.

12. Each tool head advanced by feed to point of positive stop which is located on face of column and adjusted as required in relation to tool-head location with peak of cam. (An adjustable amount of tool-slide travel may be had in a horizontal or angular direction.)

13. Tool head returned rapidly to initial position by cam on feed drum.

14. Control-drum locks (one for each tool head) released by return of head to initial position, which also disengages the rapid-motion feed clutch.

15. Control drum released by return of the head completing longest operation.

Function 4 then recurs and the operating cycle 4 to 15 is repeated.

Functions 4 to 9 inclusive take place during one revolution of the control drum and are performed in a total time of 3 sec.

Typical Jobs.—The successful operation of these machines, as with all others, depends on the selection of the proper lubricat-

ing oils. For the Mult-Au-Matic the builders recommend certain oils that should be used to secure best results.

A typical job is shown in Fig. 17. This illustrates the first chucking of a forged wheel hub on a six-station machine. The operations include turning, facing, reaming, and multiple drilling. A second chucking on another machine completes the other side of the hub.

A similar machine—except that the work spindle carries a center and means for driving the work which is supported by a

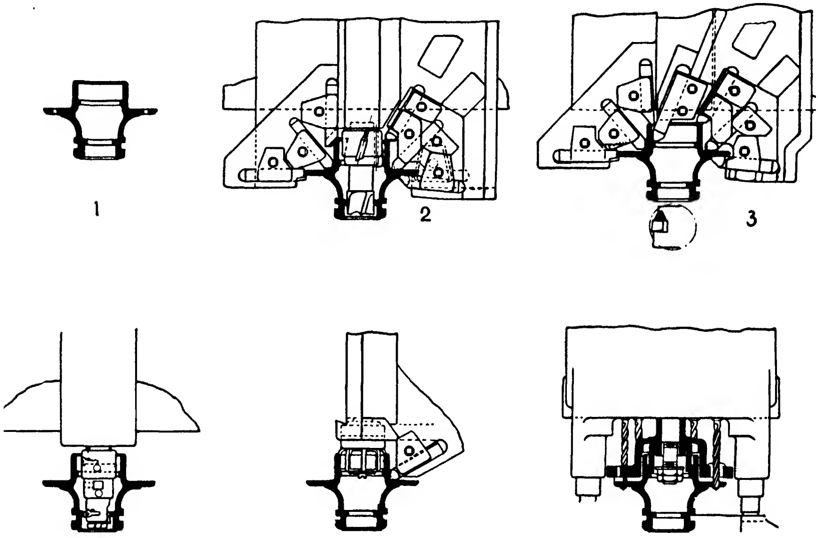


FIG. 17.—Typical Mult-Au-Matic job.

dead spindle—is used for turning work between centers. It is in reality a semi-automatic vertical, multispindle turning lathe for machining shafts and similar work within its capacity. Its operations are confined to turning, facing, and threading, as in a lathe. It has characteristics as to feeds, speeds, lubrication, and other features similar to those of the chucking Mult-Au-Matic.

There is also a recent modification of the large machine in the shape of the single spindle semi-automatic lathe shown in Fig. 18. It has a plain, vertical center slide for boring and two universal slides, each of which swivel for angular cutting. The main operating handle starts one or more heads at rapid traverse

toward the work. The heads automatically trip into the desired feed and return rapidly at the completion of the feed stroke. Any head can be neutralized at will, for tool setting. It handles work 10 in. in diameter by 32 in. high when using cross slides, or 36 in. with center slide alone. It swings 18 by 17½ in., under the side heads.

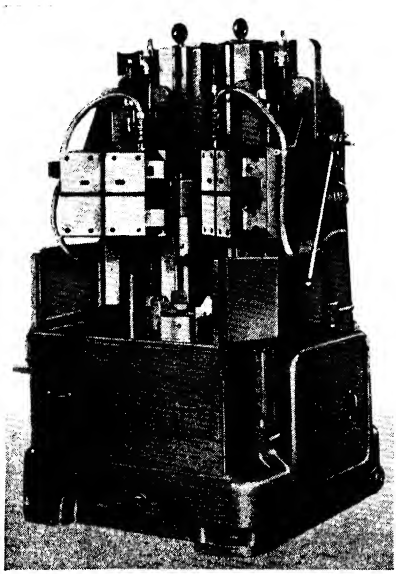


Fig. 18.—Single spindle semi-automatic.

LARGE BORING-MILL WORK

Very large boring mills, such as the 35-ft. machine shown in Fig. 19, must do a variety of work, to prevent both idle time and the shifting of work weighing many thousands of pounds. The size of the job shown, in the plant of the Newport News Shipbuilding and Dry Dock Company, can be estimated by the capacity of the machine and the man beside it. The work is larger than the rotating table, which can just be seen underneath, and is supported by the heavy box castings extending from the table itself.

In addition to boring, large machines of this kind are frequently made with the heads so arranged as to operate as slotters, carrying the tool in a vertical position for finishing flat surfaces lengthwise

of the bore. In others the housings carrying the cross rail can be moved back from its regular position, to accommodate extra diameters of work.

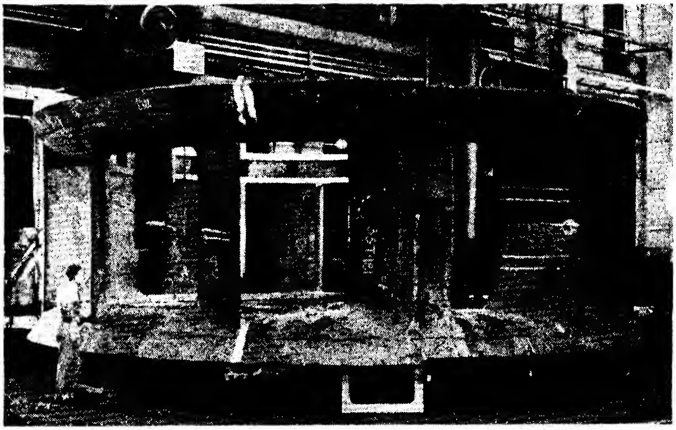


FIG. 19.—Swinging work larger than the table.

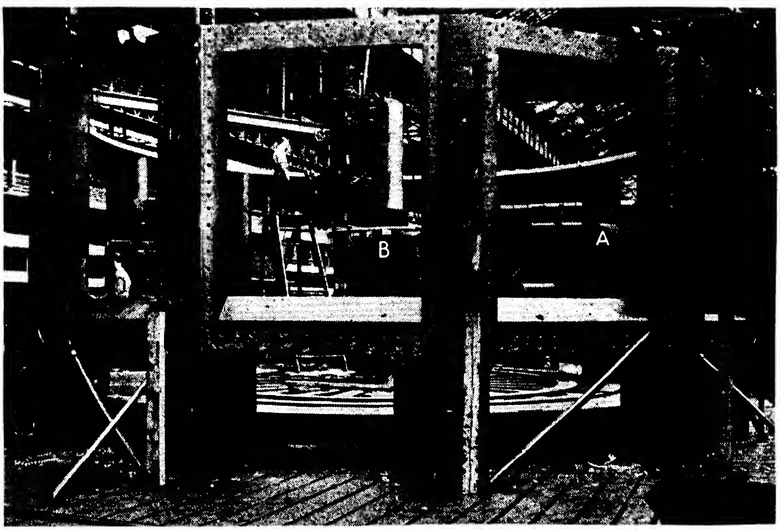


FIG. 20.—Work stationary, slotter on table.

Another large piece of work is shown in Fig. 20. This is a special form of boring apparatus in which the large revolving table in the center is driven from beneath the floor. For boring,

the machine or boring head, as at A, is bolted to the table and turns with it, machining the inner surface as it turns. A special slotter is seen at B, and can be moved to any part of the interior surface by the same table, which is, of course, stationary while the slotter is at work. The holes around the openings, on the outside, are drilled and tapped by a horizontal spindle machine on the order of a floor boring machine. Work of this kind can be handled satisfactorily only by large plants.

LARGE BORING OPERATIONS

An interesting boring operation on cylinders for the triple-expansion engines mentioned above is shown in Fig. 21, which illustrates a high-pressure cylinder being bored to 27 in. to receive its liner. The machine used has a special head consisting of a spider-shaped casting adapted to receive four heavy boring tools, each independently adjustable and each taking its share of the total cut in machining the 27-in. bore.

The work is handled in a big Giddings & Lewis horizontal boring, drilling, and milling machine with a 7-in.-bar capacity. This is one of several of these very large boring machines that are used on all sizes of cylinders and on various other big jobs in the plant.

The spider cutter head is mounted on the 7-in. bar and makes a very rigid setup for rapid and smooth machining of the work. This boring operation follows the milling of certain surfaces, which is accomplished by large inserted-tooth mills for taking broad facing cuts and by other types of milling cutters according to the kind and size of the surface to be finished in this manner. These milling operations are performed while the work is mounted on the special table on the big horizontal boring machine, and thus a variety of heavy operations can be accomplished with relatively simple setting-up processes.

Machining Large Diesel-engine Liners.—Figure 22 shows the machining of one of a number of liners bored in a large lathe at the shop of the General Engineering & Dry Dock Co. in San Francisco. These liners are bored to 33³⁄₁₆ in. diameter and are 6 ft. 8½ in. long. They are made for the largest marine Diesel engines ever built—eight-cylinder, double-acting, four-cycle units.

For boring, the cylinder liner is located in a cradle provided

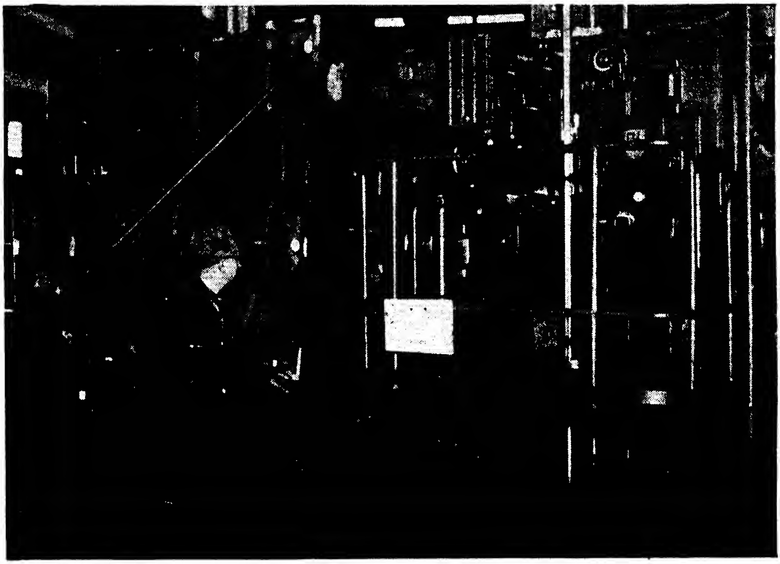


Fig. 21.—Boring high-pressure cylinder of triple-expansion marine engine.

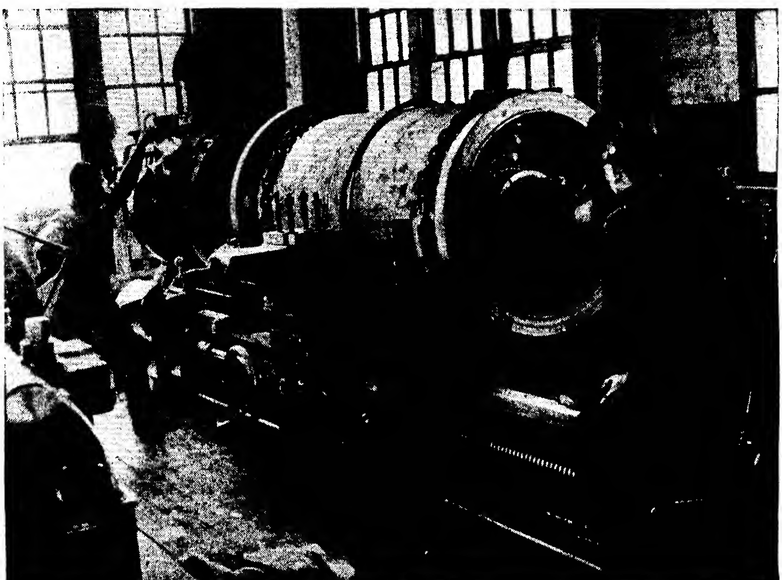


Fig. 22.—Boring lines for Diesel-engine cylinders with a three-tool head.

with heavy end plates cut out in an arc of suitable radius and mounted on the lathe bed. The boring bar is 9¾ in. in diameter and carries a spider with three arms for as many boring tools, all independently adjustable, to divide the cut properly. A star feed of the usual type is employed for traversing the boring head through the liner.

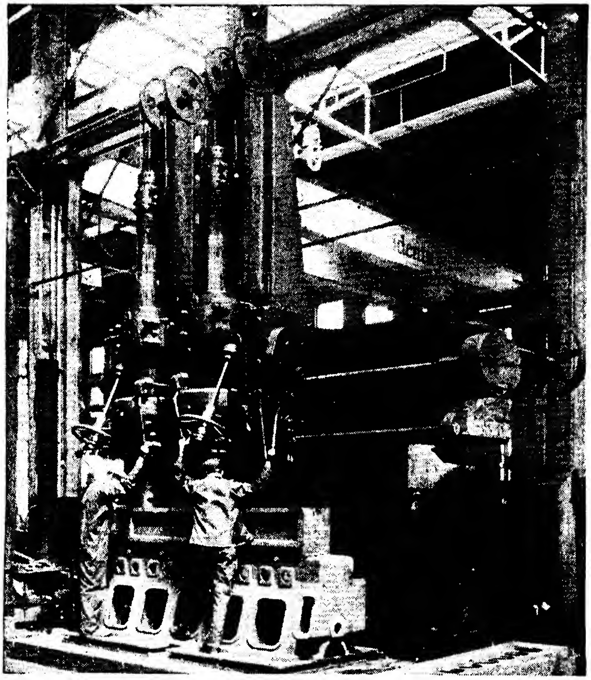


FIG. 23.—Large vertical-cylinder borer.

Three roughing cuts are taken through the work, each approximately ⅜ in. deep. The rate of feed for these cuts is ⅛ in. The boring is conducted at the rate of 5 r.p.m., or at about 45 ft. per minute surface speed. An idea of the size of this big liner may be had if the size of the men and the size of the work in the lathe are compared.

Vertical-cylinder Boring.—Vertical-cylinder boring machines vary widely in design. The one shown in Fig. 23 is not found in many shops. The two boring bars are spaced so as to bore every other hole in the cylinder block of the Diesel engine shown. The boring head is mounted on a heavy cross rail which is sup-

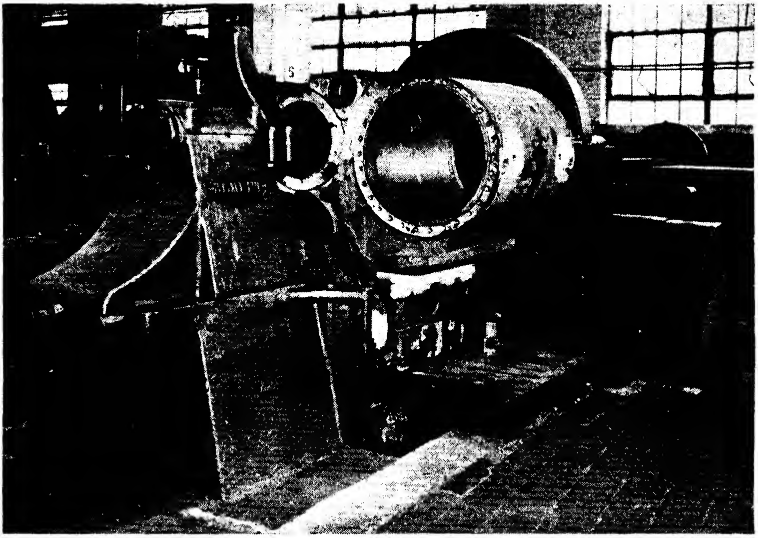


FIG. 24.—Special cylinder boring machine.

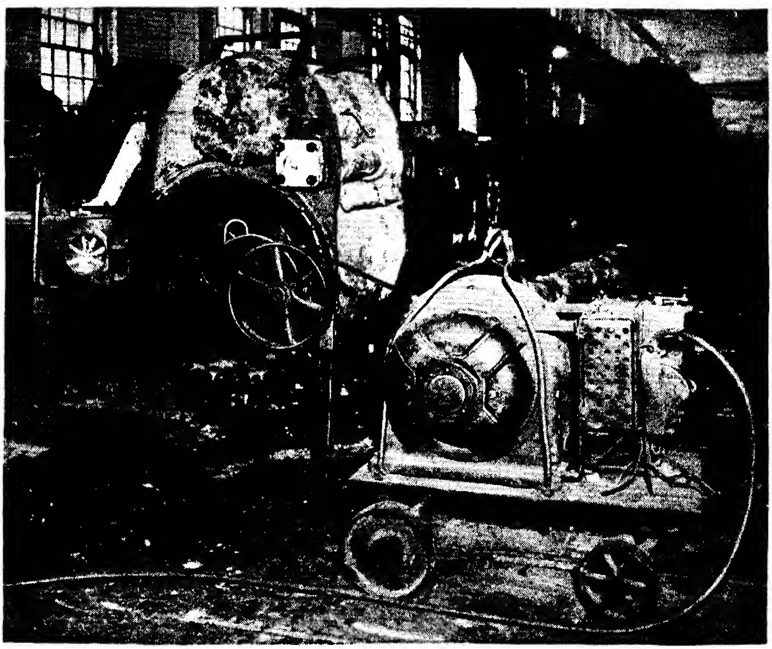


FIG. 25.—Portable cylinder borer.

ported at the top of a massive column. A floor plate in front of the column holds the work to be bored. The bar itself is driven by a quill or sleeve on the outside and feeds through the quill as it bores its way down through the bore of the cylinder.

Locomotive-cylinder Borer.—A special horizontal boring machine is seen in Fig. 24. This is designed and built entirely for boring locomotive cylinders and similar work. As shown, the large or main cylinder has been bored and the boring bar is at work in the valve chamber. The arm, shown in its top position, carries a tool which faces the ends of the cylinders. The star wheel at the end of the arm is turned by a projection fixed on the machine, this being the regulation star feed.

Portable Boring Bar.—A portable boring bar is shown at work on a locomotive cylinder (Fig. 25). This bar is supported at each end by a frame that fastens to the frame of the locomotive. It is driven by the belt from the portable motor, which permits it to be used in any part of the shop. The gear reduction from the pulley to the bar itself is covered by the metal case for safety. The boring head carries either one or two cutters and is fed by a screw sunk in a recess planed lengthwise in the bar itself. This screw is turned by the well-known star-feed device which has been mentioned before.

SINGLE-POINT BORING

Although, for accurate work, toolmakers have for years resorted to single-point boring with "fly cutters," the use of this method for finishing holes in mass production is of recent origin. Beginning with the finishing of babbitt bearings and piston pin holes, the method has been adopted by many industries where precision finishing of holes is necessary. Until recently this method has been confined to comparatively small holes, but latest developments include the finish machining of cylinder bores for automobiles. A machine for this work will be described later.

Accurate boring of this kind means that all bearings must be of the best material, that all spindles must be in alignment, that spindles and the tools they carry must be in balance, and that the boring bars must not deflect because of lack of stiffness in either bar or machine. As a rule, machines of this type use V belts as the method of driving.

One large field for this type of machine is in the boring of parts

for household refrigerators, where tolerances are very small and fits must be maintained. These machines, under different trade names, are built with varying numbers of spindles to suit the work in hand. They were originally called "diamond boring machines" because diamonds were then used as the cutting tools. While this name still prevails to some extent, the different sintered carbides are now used almost exclusively as the cutting tools.

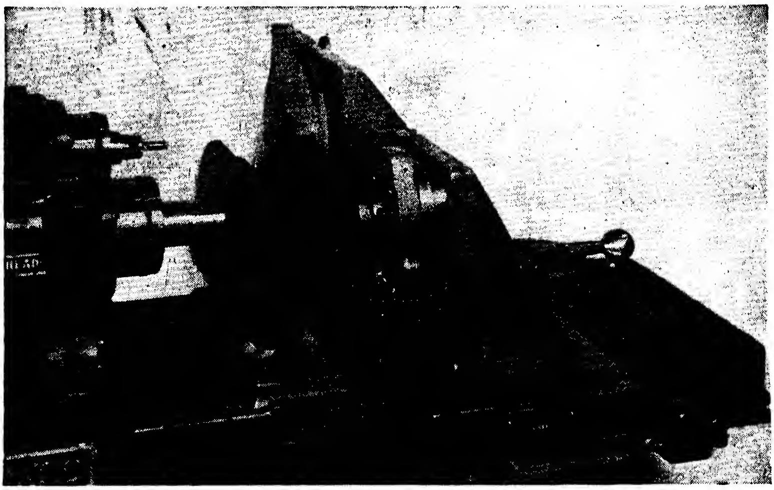


Fig. 26.—Heald Bore-Matic at work.

One well-known machine for this work is built by the Heald Machine Company under the name of Bore-Matic. Work done by this type of machine is called "borizing." Close-up views of some of these machines are shown in Figs. 26 to 29. In Fig. 26 is seen the front side of a fixture and two boring bars of widely varying diameters. This, together with Fig. 27, gives a good idea of the way in which work is held and the clamping methods used. Cam operated toggles give a rapid and sure method of holding the work.

Two views of another job are seen in Figs. 28 and 29. Here both pieces are held by the single cam lever at the top, and this is a turning instead of a boring operation. A welded-chip chute is shown beneath the two eccentrics being turned. In Fig. 28 both turning tools, which are really hollow milling cutters with but a single cutting point, can be seen. These machines can be readily

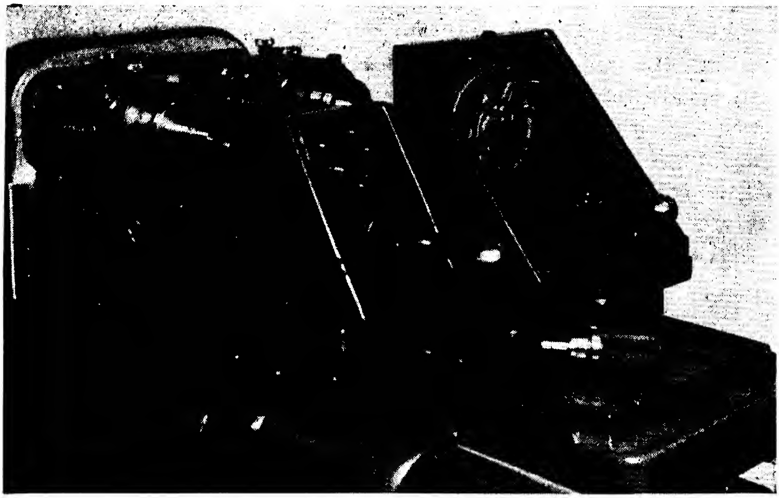


FIG. 27.—Rear view of Fig. 26.

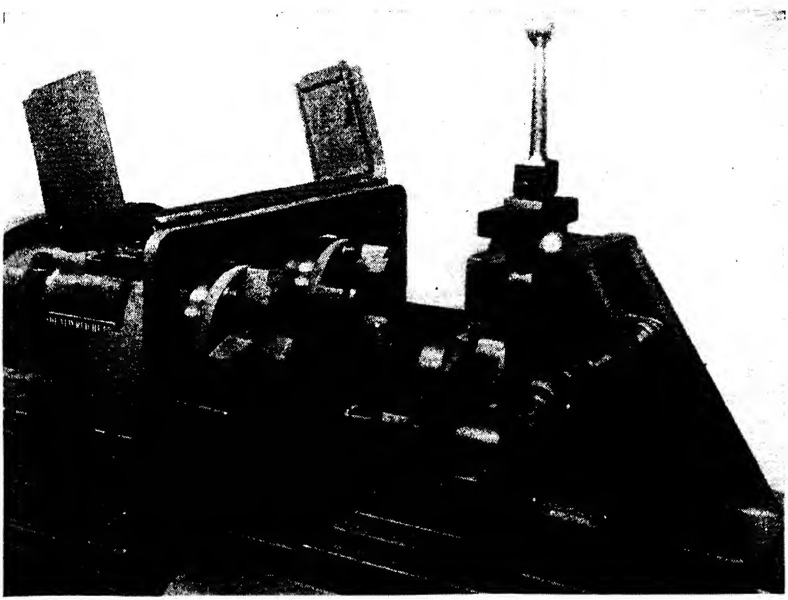


FIG. 28.—Hollow turning tools.

retooled for different jobs and have a large range. One machine, for example, bores holes from $\frac{1}{4}$ to 4 in. in diameter and has a maximum stroke of 7 in. Table feeds run from 1 to 15 in. per minute and they may be classed as semi-automatic machines.

Adjustable boring heads are used in some classes of work, one of these being shown in Fig. 30. These tools are really refined offset boring heads that have been used in tool rooms for years, but the newer tools are more rigid and more convenient in most

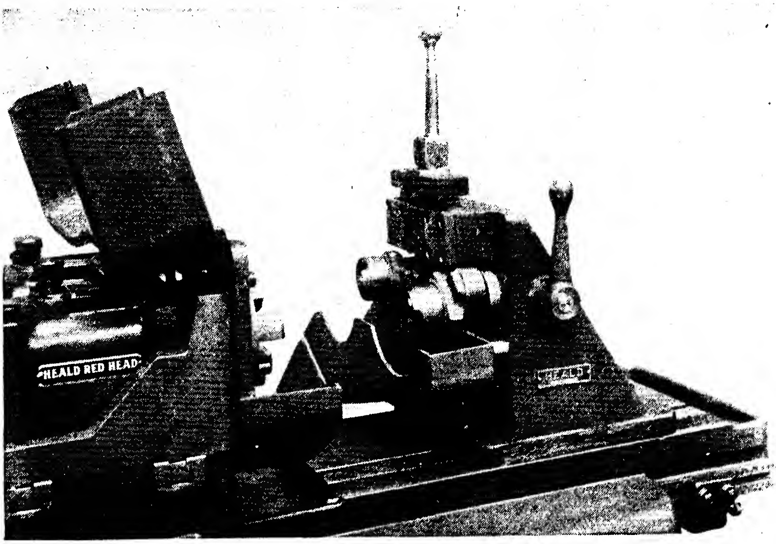


FIG. 29.—How the work is held.

instances. The tool shown can be adjusted very accurately by the graduations on the outer diameter. Each mark indicates a change at 0.0002 in. in the diameter of the hole bored.

Single-point Automobile Work.—Single-point boring is being used in many automobile operations, some of them running up to fair-sized holes. In Fig. 31 an Ex-Cell-O machine is boring the lengthwise hole in a differential carrier finishing this bore before the cross holes are bored. The cut is light and the size of the bar gives an indication of the accuracy that can be secured.

The second operation is shown in Fig. 32 where the carrier is located on the previously bored center hole. These cross holes are $3\frac{5}{32}$ in. in diameter and $1\frac{3}{16}$ in. long. The cut is only 0.012 to 0.015 in., which permits extreme accuracy to be secured. The

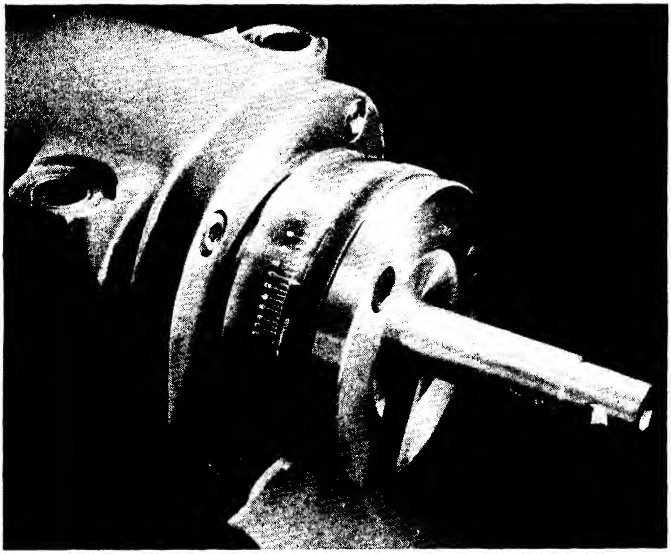


Fig. 30.—Heald adjustable micrometer boring head.

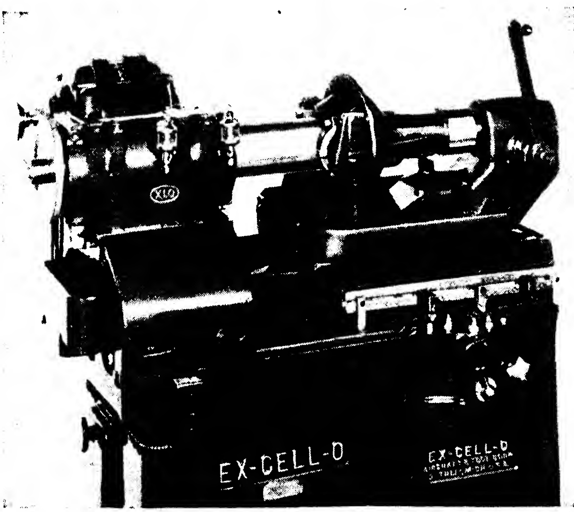


Fig. 31.—Ex-Cell-O single-point boring machine.

material is cast iron in this case. The carrier itself is seen in Fig. 33.

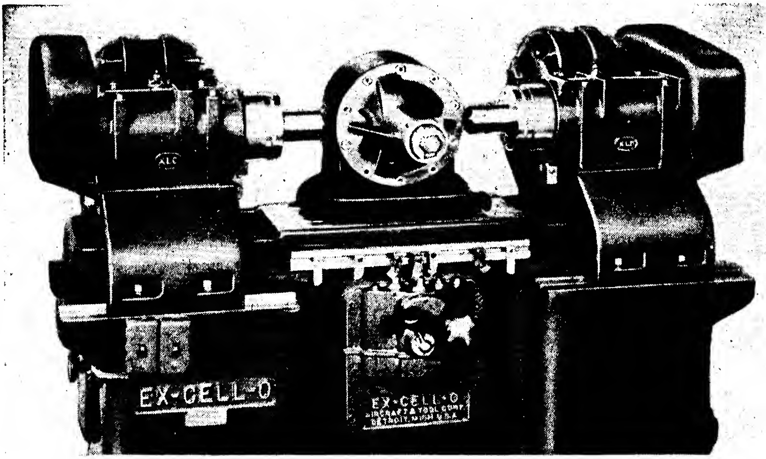


FIG. 32.—The second operation.

A much larger single-point machine is seen in Fig. 34, where the eight holes of a V block are being finished with single-point sintered-carbide tools. Each boring bar has its own motor and

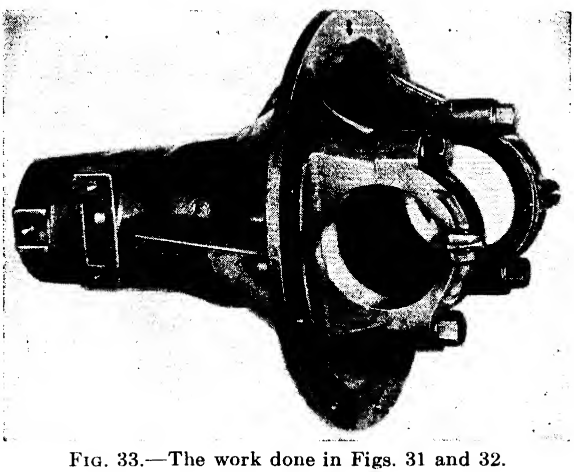


FIG. 33.—The work done in Figs. 31 and 32.

is driven by V belts which give a very smooth action. After the holes are bored, the boring bars are moved a short distance to one side, so as not to leave a mark in the cylinder when they

are withdrawn. The amount of metal removed is about the same as in the differential carrier and leaves approximately 0.0005 in. for honing.

The eight spindles are so spaced as to bore every other hole in the cylinder block; the block is then indexed to the adjoining hole. By placing two blocks in the machine in tandem, a complete block comes off the machine at every pass of the bars, after the first.

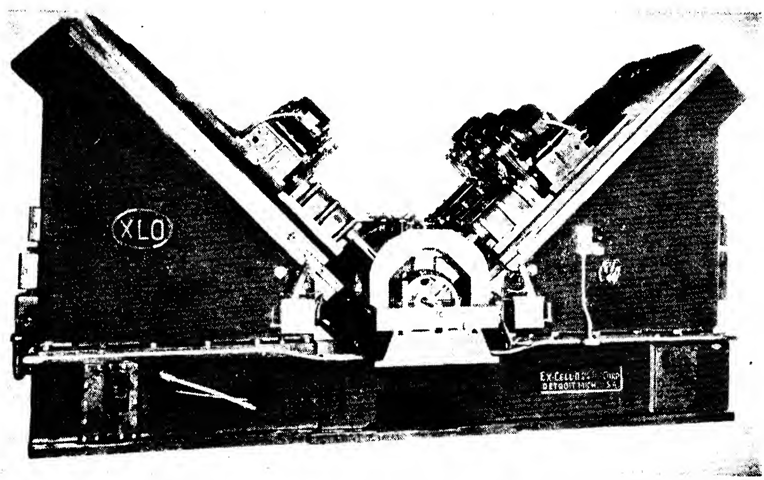


FIG. 34.—Large single-point machine finishing eight cylinder bores at once.

Boring Pistons.—An interesting method of boring piston pinholes is seen in Fig. 35. A double, air-operated fixture locates and clamps two pistons at once. One pair of bars rough-bores the holes and the other bars give the finishing cut. The table feeds the pistons to the left until both holes are bored through on both sides; then the table reverses and feeds the finishing cutters clear through both holes. This assures perfect alignment and correct diameters. The machine shown in the illustration is a Heald Bore-Matic.

A method of turning pistons on an Ex-Cell-O machine is seen in Fig. 36. Two pistons can be turned at one operation. The front spindle is empty to show the construction of the mandrel which holds the work. The V-s locate the piston-pin bosses, and the piston is drawn back against the chuck by air.

The single-point tools shown under the nozzles which supply

coolant, are mounted in a swinging carrier whose movement is controlled by a cam on the spindle at the end of the piston. This

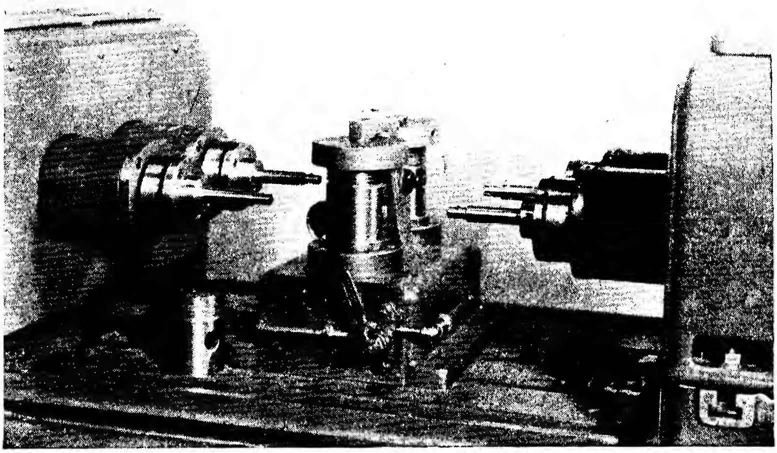


Fig. 35.—Rough and finish boring pistons.

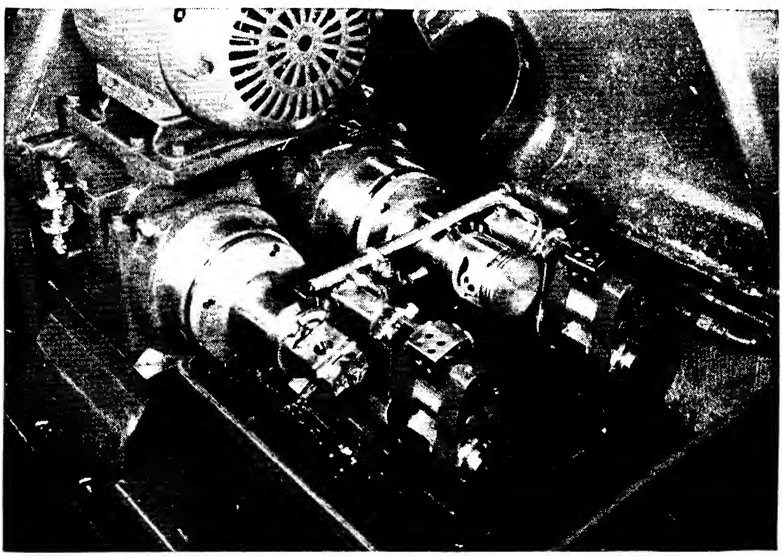


Fig. 36.—Turning aluminum pistons in another machine.

cam moves the tool to and from the work sufficiently to give the desired relief in diameter at the proper points. Some of these machines run over 3,000 r.p.m. on aluminum pistons.

Precision Boring.—The Heald Machine Company, pioneers in precision boring, have coined the word "borizing" to describe their method of single-point tool work in boring, turning, and even producing flat surfaces by the use of a single-point tool, or fly cutter. Originally known as "diamond boring" because

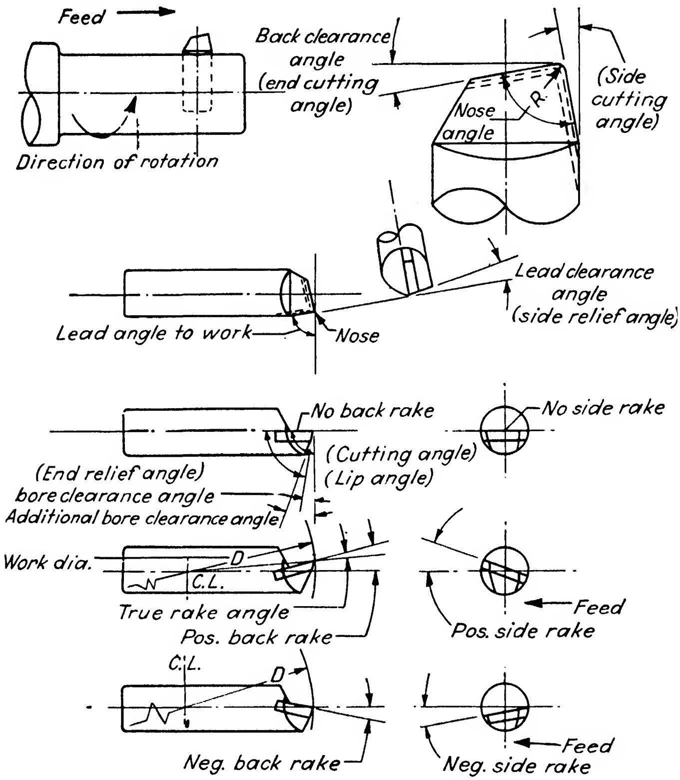


FIG. 37.—Single-point tools and the names of angles used.

diamonds were first used in this work, it has become a standard method for securing the greatest precision yet known in machine work. It produces holes that are round and straight and that have a remarkable finish, as measured by the profilometer.

High speeds and proper cutting tools are necessary to secure these results, and the following data regarding this work are the result of years of experience along this particular line. Carbide tools are necessary for this work unless for particular places

where the diamond is still considered preferable. The Heald Company's suggestions as to these tools are given in Table I. Speeds and feeds are shown in Tables II and III.

TABLE I.—CARBIDE TIP GRADES

Material	Carboloy		Kenna metal		Firthite		Ramet	
	Tip No.	Hardness	Tip No.	Hardness	Tip No.	Hardness	Tip No.	Hardness
Steel:								
Rough.	78C	89.8	. . . .	. . . .	. . . .	. . . .	EE	90.5
	78B	91.0	KM	90.6	. . . .	. . . .	EM	91.2
	78	91.7	KH	91.3	. . . .	. . . .	X	90.0
	. . . .	. . . .	. . . .	. . . .	T-04			
	. . . .	. . . .	. . . .	. . . .	T-89			
Finish.	907	91.5	K3H	91.6				
	831-A	92.5	K4H	92.3	T-31	92.5	E	92.0
	. . .	. . . .	. . . .	. . . .	TA	91.5		
	. . . .	. . . .	. . . .	. . . .	T-16			
Cast iron:								
Rough.	44A	90.0	. . . .	. . . .	. . . .	. . . .	2A68	91.0
	883	91.8	. . . .	. . . .	HC	. . . .	2A5	92.0
	. . . .	. . . .	. . . .	. . . .	H	. . . .	2A3	89.3
	. . . .	. . . .	. . . .	. . . .	T-04			
Finish.	883	91.8	. . . .	. . . .	HA	91.0	2A5	92.0
	905	92.0	. . . .	. . . .	. . . .	. . . .	2A7	92.5
	999	92.5	. . . .	. . . .	. . . .	. . . .	2A9	92.9
Aluminum:								
Rough.	44A	90.0						
	907	91.5						
	883	91.8	. . . .	. . . .	. . . .	. . . .	2A5	92.0
	905	92.0	. . . .	. . . .	HC	. . . .	2A7	92.5
	. . . .	. . . .	. . . .	. . . .	H			
Finish.	907	91.5	. . . .	. . . .	HA	91.0		
	905	92.0	. . . .	. . . .	. . . .	. . . .	2A7	92.5
	999	92.5	. . . .	. . . .	. . . .	. . . .	2A9	92.9
Copper alloys. .	883	91.8	. . . .	. . . .	HA	91.0	2A5	92.0
	905	92.0	. . . .	. . . .	. . . .	. . . .	2A7	92.5
	999	92.5	. . . .	. . . .	. . . .	. . . .	2A9	92.9
Plastic.	883	91.8	. . . .	. . . .	. . . .	. . . .	2A5	92.0
	905	92.0	. . . .	. . . .	. . . .	. . . .	2A7	92.5
	999	92.5						

Figure 37 shows the single-point tools that are recommended and gives the names of the different angles. Not all of these

names conform to the American standard, but those in brackets are the same.

Table IV shows the angles that will clear bores of different diameters and those recommended for the two groups of materials. It gives clearance angles necessary when the cutting point is at the center of the bore and at three heights above the center.

TABLE II.—SPEEDS AND FEEDS FOR SINGLE-POINT BORING TOOLS

Metal	Feet per minute	Finish feed per revolution of tool
Aluminum	1,000–6,000	0.001–0.005
Babbit and silver	1,000–2,000	0.001–0.003
Bronze:		
Class 1	800–4,000	0.001–0.005
Class 2	500–2,000	
Class 3	500–1,000	
Cast iron:		
Soft	Up to 750	
Medium	Up to 500	0.003–0.006
Hard	Up to 300	
Steels	See S.A.E-cutting speed chart	0.004–0.008

Standard tool front and side clearance angles are given in Table V. This shows the side clearance angle produced by 12 different side angles in connection with 22 front clearance angles. It makes a very complete reference for tool angles and clearances.

Figures 38 to 41 give details of tools recommended for cast iron, bronze, aluminum, and steel, with all necessary details.

Table for S.A.E. Steels.—There is also a special table for S.A.E. steels, in Table VI. This is very complete and easily understood. It includes steels from 1010 to 51210.

Following each steel is a key number which refers to the key numbers in the left-hand column of the chart. Heavy lines indicate steel that has been annealed and also heat-treated steels in three degrees of Rockwell hardness. From these it is easy to see what surface speeds can be used in cutting the different materials.

Steels 1010 to 1020 have the index number of 4. If they are annealed, follow the line below figure 4 in the key column to the last heavy line on the chart. Go down from there to the lower

TABLE III.—SPEEDS AND FEEDS FORMULAS

$$\text{Boring time, seconds} = \frac{\text{length of bore}}{\text{table travel, in. per min.} \times 60}$$

$$\text{Table travel, in. per min.} = \text{lead} \times \text{r.p.m.}$$

$$\text{Lead} = \frac{\text{table travel, in. per min.}}{\text{r.p.m.}}$$

$$\text{R.p.m.} = \frac{\text{table travel, in. per min.}}{\text{lead}}$$

$$\text{R.p.m.} = \frac{12 \times \text{surface ft. per min.}}{3.1416 \times \text{diam. of work, in.}} = 3.820 \times \frac{C}{D}$$

$$\text{Cutting speed, or surface ft. per min.} = 0.262 \times D \times \text{r.p.m.} = \frac{3.1416 \times \text{diam. of work, in.} \times \text{r.p.m.}}{12}$$

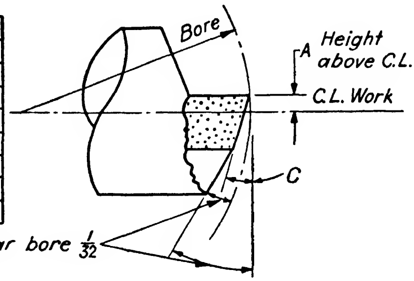
$$\text{One inch of table travel in seconds} = \frac{60}{\text{table travel, in. per min.}}$$

Table travel, in. per min.	½	¾	1	1¼	1½	1¾	2	2¼	2½	3¾	3	3¼	3½	3¾	4	4¼	4½	5	5½	6	6½–7	7½–8	8½–9	9½–10½	11–12
Seconds required for 1 in. of table travel	120	80	60	48	40	34	30	27	24	22	20	18	17	16	15	14	13	12	11	10	9	8	7	6	5

line. This shows that annealed 1010 steel can be machined at 1,360 ft. per minute. Take 5150 steel and key number 11.

TABLE IV.—BORE CLEARANCE ANGLES

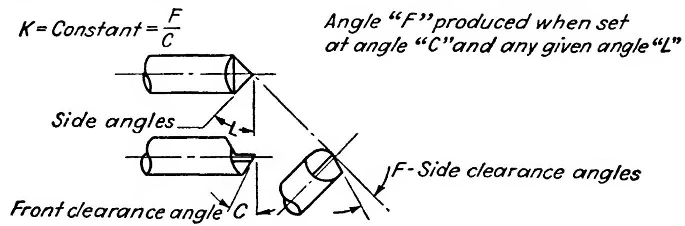
Materials	
Group I	Group II
Brass	Aluminum
Bronze	Copper
Cast iron	Fibre
Cast steel	Magnesium
Malleable iron	Plastics
Semi-steel	Rubber
Steel	Zinc alloy



Bore	First bore clearance angle C, degrees							
	When A = 0		When A = 0.010		When A = 1/32		When A = 1/16	
	Material		Material		Material		Material	
	Group I	Group II	Group I	Group II	Group I	Group II	Group I	Group II
5/16	10	13	9	12	3	5		
3/8	10	13	9	12	4	6		
7/16	10	13	9	12	5	7		
1/2	10	13	9	12	6	8		
5/8	10	13	9	12	6	9	2	4
3/4	10	13	9	12	6	9	2	5
7/8	10	13	9	12	6	9	2	5
1	10	12	8	11	6	9	2	5
1 1/4	9	12	8	11	6	9	3	6
1 1/2	9	12	7	10	6	9	3	6
1 3/4	8	11	7	10	6	9	4	7
2	8	11	7	10	6	9	4	7
2 1/2	7	10	6	9	6	9	4	7
3	7	10	6	9	6	9	5	8
3 1/2	7	10	6	9	6	9	5	8
4	6	8	6	9	6	9	5	8
5	6	8	6	9	6	9	5	8
6	6	8	5	8	6	9	5	8

If this is annealed, it can be machined at 540 surface ft. per minute. If it is heat-treated to 28–35 Rockwell hardness, the cutting speed can only be 280 surface ft. per minute.

TABLE V.—STANDARD TOOL FRONT AND SIDE CLEARANCE ANGLES



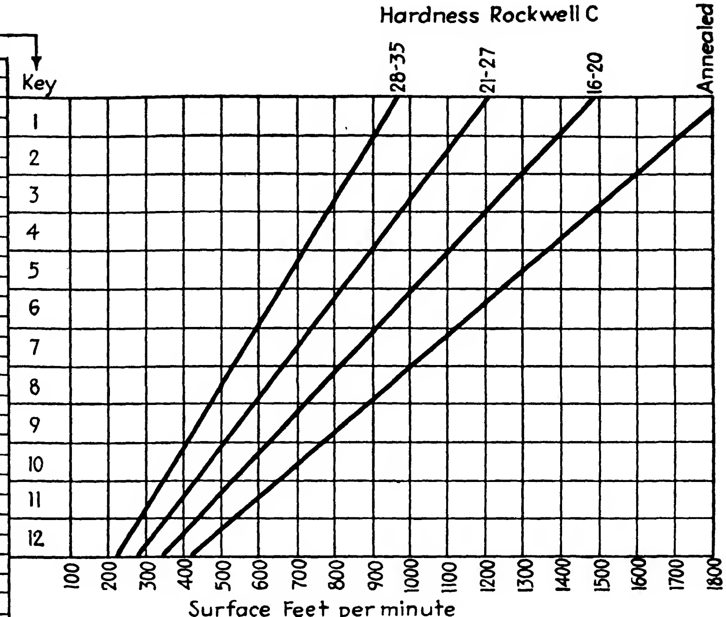
C	$L = 5°$ F $K = 0.996$	$L = 10°$ F $K = 0.985$	$L = 15°$ F $K = 0.966$	$L = 20°$ F $K = 0.940$	$L = 25°$ F $K = 0.906$	$L = 30°$ F $K = 0.866$	$L = 35°$ F $K = 0.819$	$L = 40°$ F $K = 0.766$	$L = 45°$ F $K = 0.707$	$L = 50°$ F $K = 0.643$	$L = 55°$ F $K = 0.574$	$L = 60°$ F $K = 0.500$
1°	1°0′	0°59′	0°58′	0°56′	0°54′	0°52′	0°49′	0°46′	0°42′	0°39′	0°34′	0°30′
2°	2°0′	1°58′	1°56′	1°53′	1°49′	1°44′	1°38′	1°32′	1°25′	1°17′	1°9′	1°0′
3°	2°59′	2°57′	2°53′	2°49′	2°41′	2°36′	2°27′	2°18′	2°7′	1°56′	1°43′	1°30′
4°	3°59′	3°56′	3°52′	3°46′	3°37′	3°28′	3°17′	3°4′	2°50′	2°34′	2°18′	2°0′
5°	4°59′	4°55′	4°50′	4°42′	4°32′	4°20′	4°6′	3°50′	3°32′	3°13′	2°52′	2°30′
6°	5°59′	5°55′	5°48′	5°38′	5°26′	5°12′	4°55′	4°36′	4°14′	3°51′	3°27′	3°0′
7°	6°58′	6°54′	6°46′	6°35′	6°21′	6°4′	5°44′	5°22′	4°57′	4°30′	4°1′	3°30′
8°	7°58′	7°53′	7°44′	7°31′	7°15′	6°56′	6°33′	6°8′	5°39′	5°9′	4°35′	4°0′
9°	8°58′	8°52′	8°42′	8°28′	8°9′	7°48′	7°22′	6°54′	6°22′	5°47′	5°10′	4°30′
10°	9°58′	9°51′	9°40′	9°24′	9°4′	8°40′	8°11′	7°40′	7°4′	6°26′	5°44′	5°0′
11°	10°57′	10°50′	10°38′	10°20′	9°58′	9°32′	9°0′	8°26′	7°47′	7°4′	6°19′	5°30′
12°	11°57′	11°49′	11°36′	11°17′	10°52′	10°23′	9°50′	9°11′	8°29′	7°43′	6°53′	6°0′
13°	12°57′	12°48′	12°34′	12°13′	11°47′	11°15′	10°39′	9°57′	9°11′	8°21′	7°28′	6°30′
14°	13°57′	13°47′	13°31′	13°10′	12°41′	12°7′	11°28′	10°43′	9°54′	9°0′	8°2′	7°0′
15°	14°56′	14°47′	14°29′	14°6′	13°35′	12°59′	12°17′	11°29′	10°36′	9°39′	8°37′	7°30′
16°	15°56′	15°46′	15°27′	15°2′	14°30′	13°51′	13°6′	12°15′	11°19′	10°17′	9°11′	8°0′
17°	16°56′	16°45′	16°25′	15°59′	15°24′	14°43′	13°55′	13°1′	12°1′	10°56′	9°45′	8°30′
18°	17°56′	17°44′	17°23′	16°55′	16°18′	15°35′	14°44′	13°47′	12°44′	11°34′	10°20′	9°0′
19°	18°55′	18°43′	18°21′	17°52′	17°13′	16°27′	15°34′	14°33′	13°26′	12°13′	10°54′	9°30′
20°	19°55′	19°42′	19°19′	18°48′	18°7′	17°19′	16°23′	15°19′	14°8′	12°52′	11°29′	10°0′
21°	20°55′	20°41′	22°17′	19°44′	19°2′	18°11′	17°12′	16°5′	14°51′	13°30′	12°3′	10°30′
22°	21°55′	21°40′	21°15′	20°41′	19°56′	19°3′	18°1′	16°51′	15°33′	14°5′	12°38′	11°0′

TABLE VI.—TABLE FOR S.A.E. STEELS

Select Key

S.A.E. Steel	Key	S.A.E. Steel	Key	S.A.E. Steel	Key		
1010	4	2335	11	4130	10		
1015	4	2340	11	X 4130	10		
1020	4	2345	11	4135	12		
1030	6	2350	11	4140	12		
1035	7	2512	10	4150	12		
1040	8	2515	11	4340	12		
1045	9	3115	8	4345	12		
1050	10	3120	9	4615	11		
1060	11	3125	10	4620	11		
1095	12	3130	10	4640	12		
1112	1	3140	11	4650	12		
X1112	1	X3140	11	4815	11		
1115	2	3145	11	4820	11		
1120	2	3150	11	5120	10		
X 1314	3	3230	11	5130	10		
X 1315	3	3240	12	5140	11		
X 1330	5	3245	12	5150	11		
X 1335	7	3250	12	6115	9		
T 1330	7	3312	11	6120	10		
T 1335	8	3325	11	6125	11		
T 1340	8	3330	11	6130	11		
T 1345	8	3335	12	6135	11		
T 1350	9	3340	12	6140	11		
2105	7	3415	10	6145	12		
2115	7	3430	12	6150	12		
2315	7	3435	12	30905	12		
2320	10	3450	12	51210	9		
2330	11	4115	8				

S.A.E. STEELS



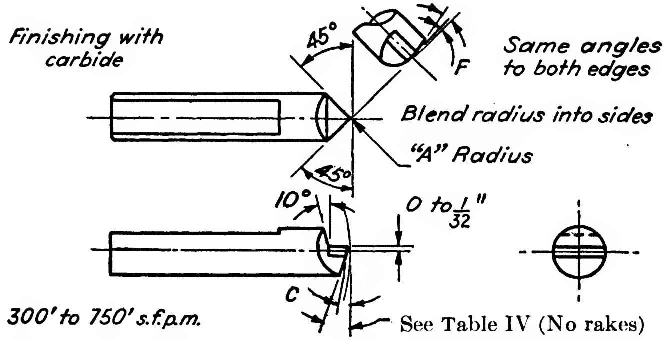


FIG. 38.—Tools for cast iron. Feed: 0.003 to 0.006 per revolution. Depth of cut: 0.005 to 0.015. S.F.P.M.: see Table II. Clearance angle varies with height of cutting point above center (see Table VII). For side clearance angles see Table V. Radius depends on finish required and pressure of boring bar on work. For small bores use 0.015 to 0.030—for large bores 0.030 to 0.060.

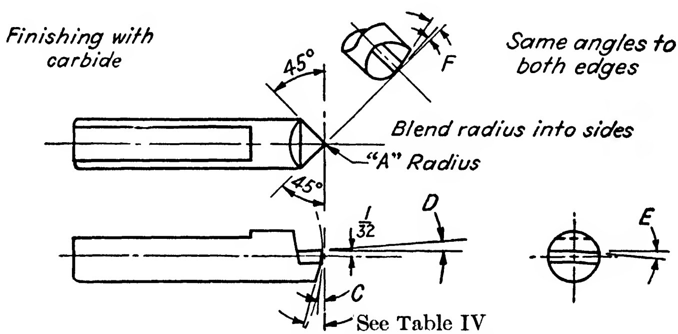


FIG. 39.—Tools for bronze. *A* radius: controlled by finish required (average radius 0.015 to 0.030 for small bores, 0.030 to 0.060 for large bores). *C* clearance angles with variation in height above center line of tool (see Table VII). *F* side clearance angles (see Table V).

Class	Cutting speed	*D*	*E*	Coolant
I	800–3000	0°	5°	Dry; paraffin oil; sol. oil 20 to 1
II	450–1500	0°– 5°	5°–10°	Sol. oil; min. oil + 10% lard oil
III	200– 800	5°–10°	15°–20°	Min. oil + 20% lard oil

Class I (free cutting alloys): leaded copper, leaded combination bronze, leaded red brass, free cutting yellow brass, forging brass, leaded naval brass. Class II (readily machinable): red brass, yellow brass, muntz metal, naval brass, tobin bronze, leaded phosphur bronze. Class III: copper, commercial bronze, nickel silver, berylium copper, chrome copper.

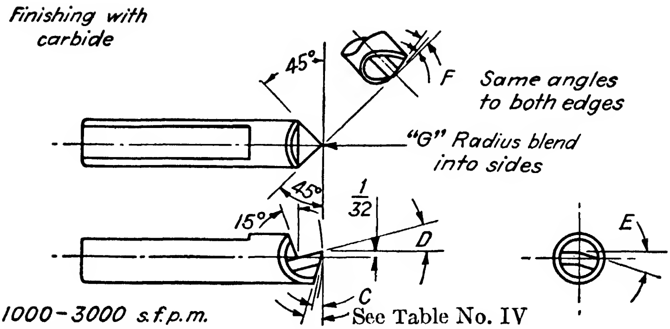


FIG. 40.—Tools for aluminum. Feed: 0.003 to 0.006 per revolution. Depth of cut: 0.005 to 0.015. *C* clearance angle varies with height of cutting point above center line of tool (see Table VII). *D* back rake angle: 0° to 15°. *E* side rake angle: 5° to 15°. *F* side clearance angle: controlled by *C* (see Table V). *G* radius: controlled by finish required, feed used, and the pressure which can be used on work or boring bar. 0.015 radius for small bores; 0.015 to 0.060 radius for large bores. Coolant: soluble oil, soda water, kerosene, and lard oil.

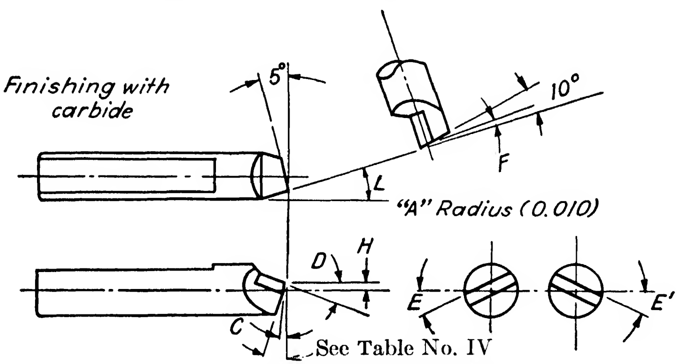
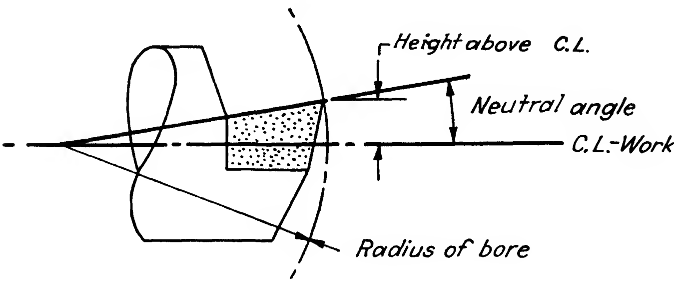


FIG. 41.—Tools for steel. Feed: 0.003 to 0.007 per revolution. Depth of cut: 0.005 to 0.015. S.F.P.M.: see Table II. *A* radius: keep small, approximately equal to depth of cut. *L* lead angle (not affected by light cuts). *C* clearance angle (see Table V). *D* back rake angle: 0° to 35° (neg.). *E* side rake (neg.): 0° to 8° (neg.). *E* side rake (pos.): 0° to 35° (pos.). *F* side clearance angle: 2° to 3° adequate. *H* this height above ℄ modifies *C* (see Table VII).

Types	*D*	*E*	*E'*	Use
1	0°– 6°	3°–8°	......	High carbon and alloy steels
2	5°–35°	....	15°–35°	Interrupted cuts and tough steels
3	3°–10°	....	0°–15°	Low carbon steels and free cutting alloys

Table VII shows a neutral cutting angle when we consider the center of the hole being bored for diameters from 5/16 to 6 in.

TABLE VII



$$\text{Sine ``Neutral angle''} = \frac{\text{Height above C.L.}}{\text{Radius of bore}}$$

Diameter of bore	Height above center line — Neutral angle					
	1/100	1/64	1/32	1/16	3/32	1/8
5/16	4°	6°	11½°			
3/8	3½°	5°	9½°			
7/16	3°	4°	8°			
1/2	2½°	3½°	7°			
5/8	2°	3°	5½°	11½°		
3/4	1½°	2½°	5°	9½°		
7/8	1°	2°	3½°	7½°	12½°	
1	1°	2°	3½°	7°	11°	
1¼	....	1½°	3°	6°	8½°	11°
1½	....	1°	2½°	5°	7°	9½°
1¾	....	1°	2°	4°	6°	8°
2	....	1°	2°	3½°	5½°	7°
2½	....	1°	1½°	3°	4½°	6°
3	....	....	1°	2½°	3½°	5°
3½	....	....	1°	2°	3°	4°
4	....	....	1°	2°	3°	3½°
5	....	....	1°	1½°	2°	3°
6	....	....	.....	1°	2°	2½°

Angles above are given to nearest ½°.

This shows that, with a 1-in. hole, an angle of 2 deg. is necessary to secure a neutral angle, and the tool must be raised 1/64 in.

above the center to secure this. With a 3½-in. hole the tool must be raised $\frac{1}{16}$ in. to secure the same angle.

The effect of the tool point on the finish is illustrated in Fig. 42, which shows what surface can be secured by using tools with different point radius. The feed per revolution is shown by the curved lines and is marked. The radius of the tool point is shown at the bottom.

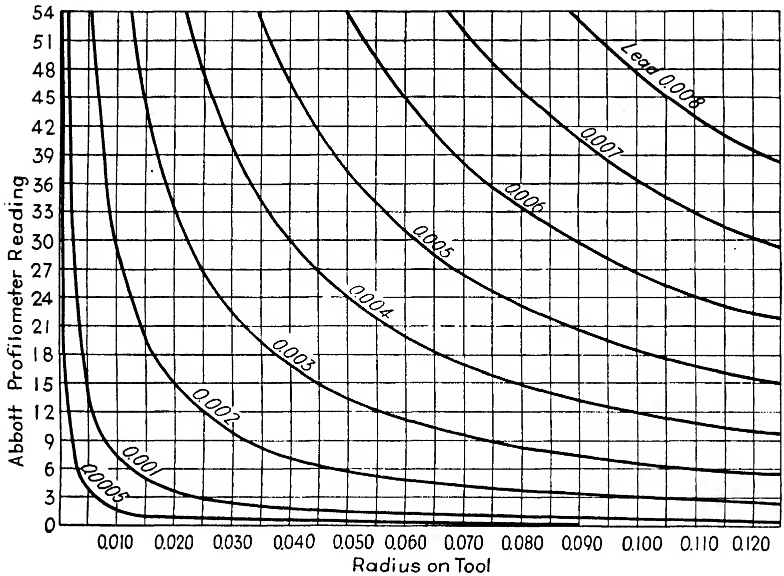


FIG. 42.—Effect of tool-point radius on smoothness of finish.

This shows that a tool-point radius of 0.030 in. and a feed of 0.004 in. give a surface of 40 microinches. Reducing the feed to 0.002 in. gives a surface of only 10 microinches. Doubling the point radius with the same 0.004-in. feed gives a surface of only 20 microinches and with the feed of 0.002 in. gives only 5 microinches. These are all valuable data for precision machining.

Boring Bars for Special Work.—The designs of boring bars, pilots, and guides are suggested by John G. Jergens of the Cleveland Pneumatic Tool Company and will be found very useful in different kinds of work. The illustrations make very little description necessary.

A simple type of boring bar is seen in Fig. 43. Here the boring tool is set at an angle in the bar to give more space between the

setscrews that hold it. Angular cutters are used in many cases, especially in small boring bars. This also has a second cutter for chamfering the end of the hole after it is bored. A facing

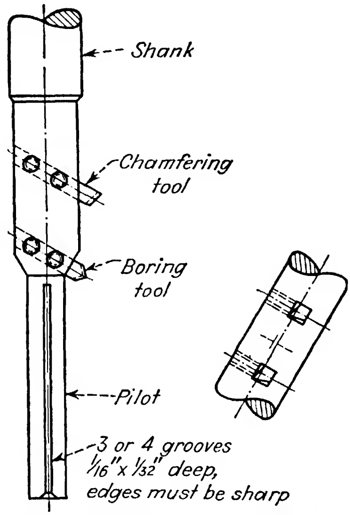


FIG. 43.—Simple type of boring bar.

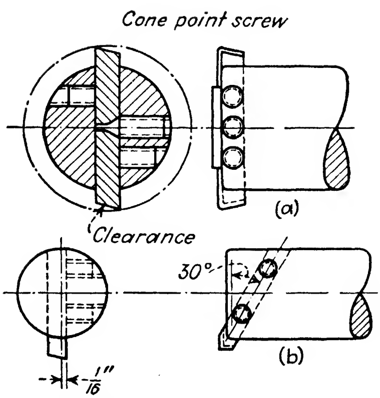


FIG. 44.—Two types of cutters—one easily adjustable for size.

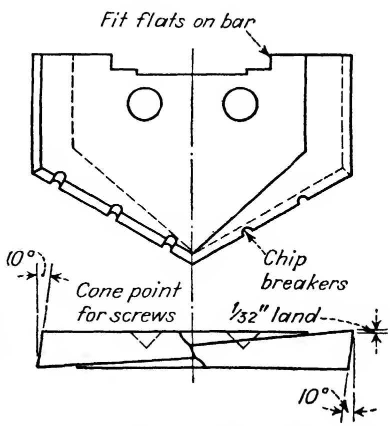


FIG. 45.—Flat cutter with center ground to reduce dead spot.

cutter could be substituted for the chamfering cutter if desired. In that case it might be better to put this cutter square with the axis of the bar although the cutting edge could be ground at the

right angle to make a square face. The pilot also shows oil grooves which permit it to be a closer fit and a better guide, than as though it was necessary to allow more space between the guide and the hole.

A boring bar carrying two cutters which are adjusted for size by using a cone-pointed screw is shown in Fig. 44 at *A*. Each cutter is locked in place by a separate setscrew. These are on

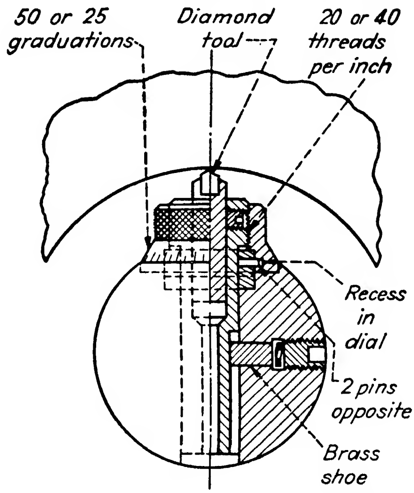


FIG. 46.—Cutter with micrometer adjustment.

opposite sides so as to hold the cutter against the side that takes the pressure of the cut. At *B* is a single cutter set at a 30-deg. angle, which is very useful in boring holes where a pilot is not necessary.

In Fig. 45 is a flat cutter which is held in the end of a boring bar and centered by the recess cut at the back end. It is held in place by cone-pointed setscrews which fit into the coned holes shown. The point of the cutter is ground from each side to reduce the dead spot and give a more nearly radial cut to the edges. By notching the edges of the cutter at alternate distances from the center, chips are broken up while preventing ridges from being formed by the notches. A small land is advisable on the sides, as shown.

Figure 46 shows a cutter that can be adjusted for accurate diameters. The cutter head has a micrometer adjustment which can be made to give any divisions desired by using 20 or 40

threads per inch and 25 or 50 graduations on the collar. Details of the construction are shown.

Three guiding bushings are shown in Figs. 47 to 49. In the first, bushing protects the drill spindle and guides it, permitting

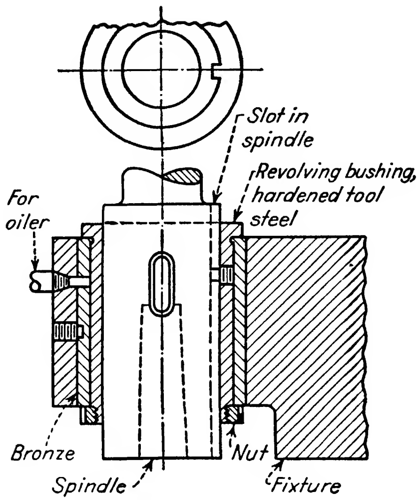


FIG. 47.—A plain, bronze guide bushing.

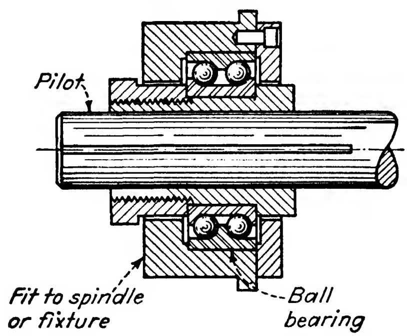


FIG. 48.—Double-row ball-bearing guide.

its end movement by use of a key in the bushing and a slot in the spindle itself. Outside the hardened steel bushing in which the spindle slides is a bronze bushing in which the steel bushing runs. This outer bushing is held stationary by the setscrew shown. It is lubricated by means of the oiler indicated at the left. This makes it possible to bore holes that are straight without depending on the stiffness or concentricity of the spindle itself.

Figures 48 and 49 show ball-bearing guides for boring bar pilots. Here the guides revolve with the pilot bar so that the pilots can be made a snug fit in the guides and prevent any lost motion between them. In Fig. 49 a felt wiper is provided to lubricate the pilot as it slides through the inner race of the ball bearing that guides it.

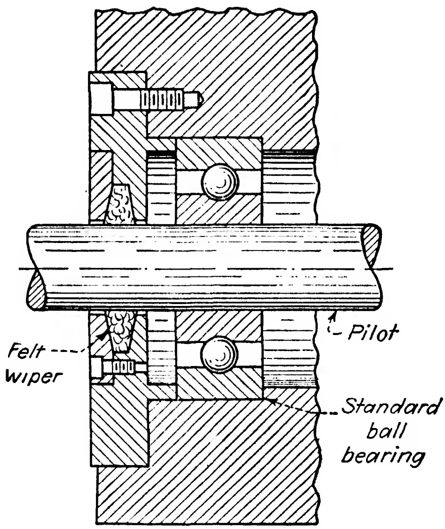


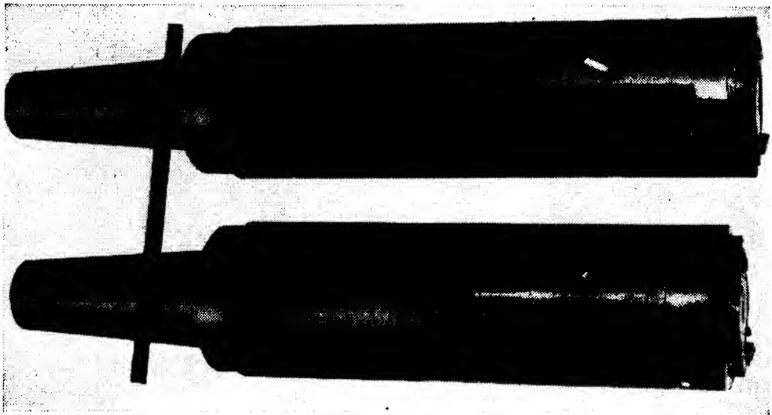
FIG. 49.—Single ball-bearing guide with felt wiper.

Boring Bars or Quills for Precision Work.—In precision boring it is very important that there be enough chip clearance between the bar or quill and the hole being bored. Otherwise the chips may crowd the bar and affect the size of the hole as well as the finish. According to Bruno Holmstrom, tool supervisor of the Heald Machine Company, a ratio of bar to hole of 0.70711 gives the bar maximum stiffness and also ample room for chips.

Table VIII shows suitable sizes for the bar for holes varying from 1¼ to 6 in., shows the chip clearance in each case, the location of the clamping screw, and the approximate distance the bar will stick through the hole when the first style is used. The table is self-explanatory.

Mr. Holmstrom suggests that the distance *E* should be given in decimals by the draftsmen as this hole is frequently used as a reference in making the boring tool itself.

The gage shown for setting the boring tools will be found useful in all the sizes listed in the table. A master bar of correct size should be used in checking and setting the dial indicator. The table and the sketches will be found very useful in this work as Mr. Holmstrom is a specialist in precision boring.



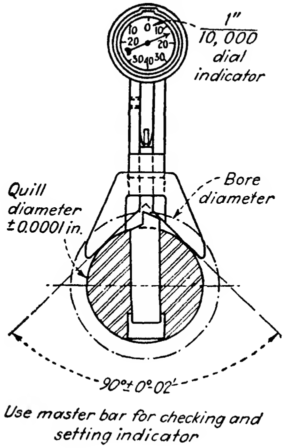
Figs. 50 and 51.—Lower bar has babbitt packing—upper bar has Insurock-plastic packing.

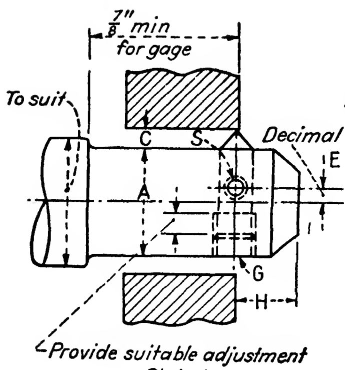
Gun Boring Heads.—Although long bores such as are found in field guns are not common in industry, the tools developed at Watertown Arsenal during the war can be applied in other forms of boring. Abandoning the old type of wood-packed boring head, which has been in use for many years, Watertown first tried babbitt as the packing (Fig. 50). The packing was cast in molds and turned to 0.007 in. smaller diameter than the bore, or cutter diameter. Although it is very heavy to handle, it holds its size very well through the length of a long bore.

Babbitt gave way to packings or linings of Insurock, which is a cotton fabric impregnated with graphite and bonded with resinoid and is commonly classed as a plastic. It is quite abrasive and must be turned with carbide tools. It is not easy to turn to size and is quite expensive, but several passes can be made without refinishing the material. The lining was turned 0.007 in. small, the same as for babbitt. This is to compensate for the wear of the cutters in the passage through a long gun barrel, this wear being from 0.003 to 0.006 in. in most cases. Some clearance is necessary as the plastic heats if the cutter wears below the size of the lining. This is seen in Fig. 51.

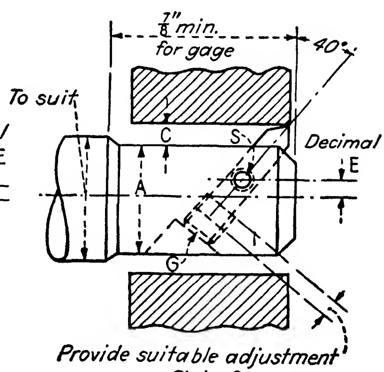
Table VIII.—Quill Dimensions Based on Quill Diameter = 0.7071 × Bore Diameter

Standard tool setting gage
for single-tool quills





Style 1



Style 2

Bore diam.	Quill style	Quill diam. *A*	Chip clear. *C*	*H*, approx.	*E*	Adjustment screw* *G*	Clamp screw* *S*	Tool diam.
1¼	1 or 2	0.884	0.183	½	3/32	⅜-34	¼-28	5/16
1½	1 or 2	0.061	0.220	½	⅛	⅜-24	⅜-24	5/16
1⅝	1 or 2	1.149	0.238	¾	5/32	⅜-24	⅜-24	5/16
1¾	1 or 2	1.237	0.256	¾	3/16	9/16-18	⅜-24	½
1⅞	1 or 2	1.326	0.275	¾	¼	9/16-18	⅜-24	½
2	1 or 2	1.414	0.293	¾	¼	9/16-18	⅜-24	½
2¼	1 or 2	1.591	0.330	¾	¼	9/16-18	½-20	½
2½	1 or 2	1.768	0.366	¾	5/16	9/16-18	½-20	½
2¾	1 or 2	1.944	0.403	¾	5/16	9/16-18	½-20	½
3	1 or 2	2.131	0.439	¾	½	9/16-18	½-20	½
3¼	1 or 2	2.298	0.476	¾	½	9/16-18	½-20	½
3½	1 or 2	2.475	0.513	¾	½	9/16-18	½-20	½
3¾	1 or 2	2.652	0.549	¾	¾	9/16-18	½-20	½
4	1 or 2	2.828	0.586	¾	¾	9/16-18	½-20	½
4½	1 or 2	3.182	0.659	¾	1	9/16-18	½-20	¾
5	1 or 2	3.536	0.732	¾	1	9/16-18	½-20	¾
5½	1 or 2	3.889	0.805	¾	1¼	9/16-18	½-20	¾

The plastic lining was made in sections, and later babbitt linings were made in the same way. On work where the Brinell does not exceed 250 there is very little trouble from cutter wear.

The cutters are set in the head at an angle of 45 deg. This gives a side-cutting edge angle of 9 deg. and an end-cutting angle

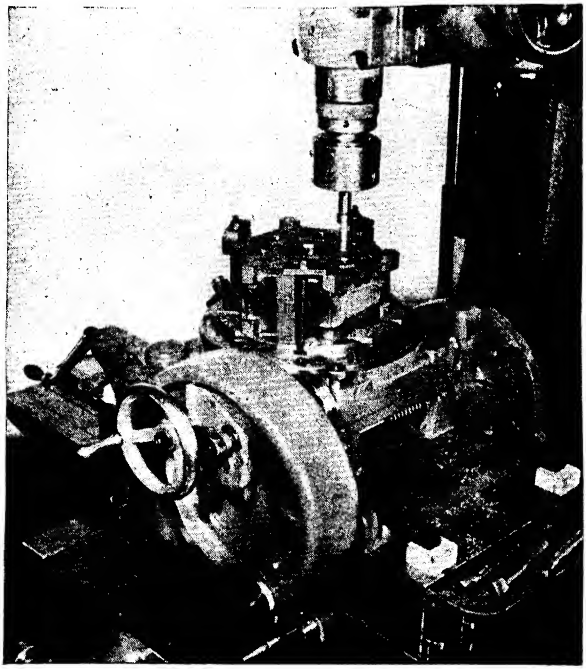


FIG. 52.—Work on Pratt and Whitney jig borer.

of 6 deg.; less than this causes a side drag which causes breakage of the carbide. The 9 deg. was found best for straightness of bore and for chip flow. A 3-deg. radial angle prevented chips from wedging between the bore and the end-cutting edge angle. A 4-deg. negative rake gave strength and prevented the cutter from digging in from any backlash in the thrust bearing.

JIG-BORING MACHINES

Jig-boring machines might almost be called heavy-duty, precision-drilling machines with tables that can be accurately spaced in two directions. Two methods are used for setting the table accurately. The Société Génèvois or Swiss machine uses

an accurate feed screw with cam corrections for their known variations. Carefully graduated scales and microscopes for setting are also used. The Pratt and Whitney machine does not depend on a screw but uses standard gage blocks between rigid stops on the machine and table. The Moore jig borer uses precision screws. Cleerman and DeVlieg use electronic controls.

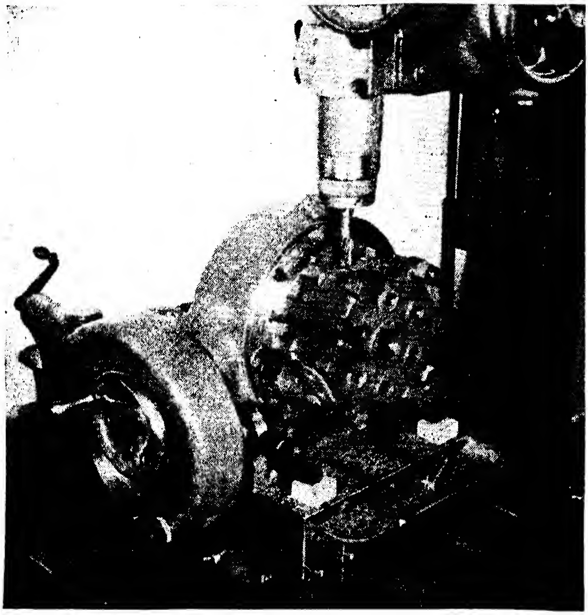


Fig. 53.—Same work tilted to another angle.

The jig-boring method has almost entirely replaced the use of toolmakers' buttons in laying out holes in jigs and fixtures. The fixture is fastened to the table of the jig borer and the holes are drilled and bored by moving the table from one position to another, the location being checked by measurements in both directions. These machines save much time over the old method of laying out with buttons and indicators.

Although primarily designed for the making of jigs and fixtures, the jig borers are being used in manufacturing where the quantity to be made does not warrant the making of a jig. After a man gets accustomed to one of these machines, he can bore any number of holes in various pieces and have them as nearly duplicated as would be obtained from the average jig. In the hands

of men trained to handle them, jig-boring machines are found to be a paying investment in many manufacturing shops where quantities are too small to stand the expense of a jig.

Two examples of the versatility of the Pratt and Whitney machines are seen in Figs. 52 and 53. These are both the same piece of work on which there are a number of operations. In Fig. 52 the central hole and the six outer holes are being bored, these being spaced very accurately by the graduated table on which the work rests.

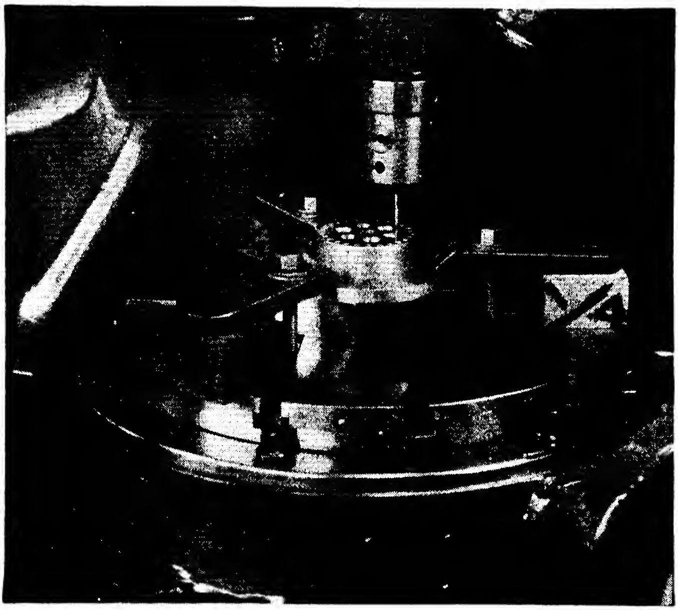


FIG. 54.—Large and small holes in this job.

In Fig. 53 the table has been swung up at 90 deg. so as to mill faces and bore holes at right angles to the top. This shows the various adjustments by which the work can be moved into any desired position and also the way in which the gage blocks are used in setting the table in both directions. Locations are checked by standard distance blocks and dial gages.

Figure 54 is entirely a boring job, but the number of holes and the variation in their size make it of special interest. While the circular spacing is done by the indexing base, the relation of the boring tool to the center of the piece is determined by the adjust-

ment of the saddle which is secured by the use of the gage blocks. This also shows the kind of adjustable boring tool used for this work. A study of this job will show how difficult it would be by any other method.

Gage for Jig-boring Work.—In most work done on the jig borer the dimensions are given from the edge of the piece being machined. The usual method of chucking a rod in the spindle—setting it against the edge of the work and then moving the spindle over half the diameter of the rod to locate the edge—is

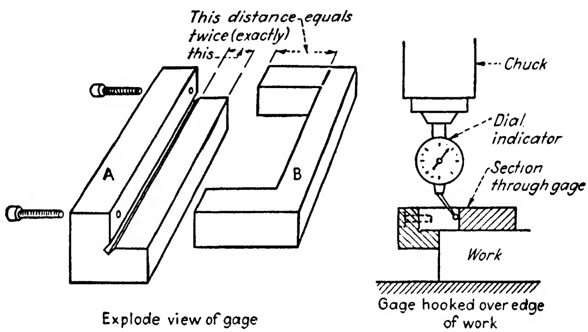


FIG. 55.—Gage for jig-boring work.

more or less of a nuisance and includes the possibility of error as well.

To avoid this, Roger F. Isetts made the gage shown in Fig. 55 which makes it easy to locate the spindle exactly at the edge of the work. The gage is made in two parts, as at *A* and *B*. Both parts are of tool steel and ground after hardening. The legs on *B* are exactly twice as long as the shelf, or lower part of *A*, so that, when the two parts are fastened together, the edge of *A* which contacts the work will be exactly in the center of the opening made by the two pieces.

Placed on the work, as shown at the right of Fig. 55, the edge of *A* is in contact with the side of the work from which all measurements are taken. Placing a dial indicator in the chuck on the spindle and turning it will show exactly when the spindle is over the edge of the work, for the indicator will read the same whether the pointer is in contact with one edge of the gage or the other.

Horizontal Jig Boring.—While the vertical jig borer is usually suitable on comparatively flat work, there is a range of tool-

room boring for which horizontal operation may be advantageous. The horizontal boring, drilling, and milling machine is often found useful for machining deep box jigs and other large work without introducing the difficulty of the operator's reaching over the work to adjust tools and to observe the cuts.

In order that dependence need not be placed on maintenance of truth of pitch of the traverse screws, which may wear unevenly

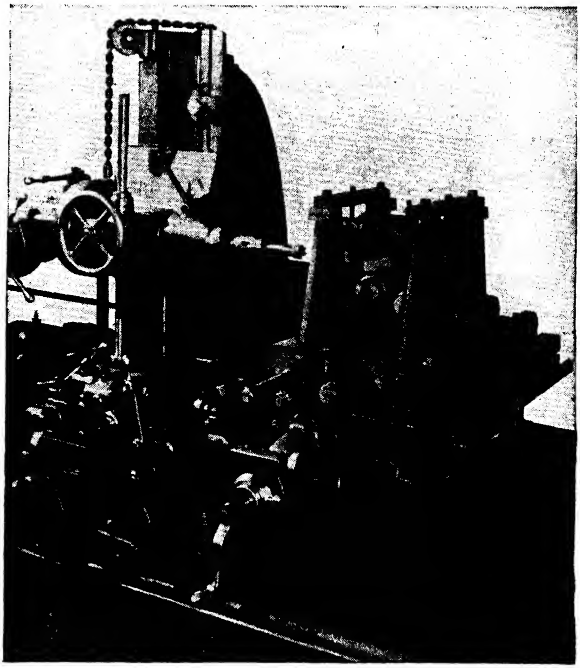


FIG. 56.—Lucas machine used as horizontal jig borer.

if used for milling, the horizontal machine may be equipped with a dial-indicator-indexing device. This has the advantage that the measuring elements do no work and therefore maintain their accuracy.

By means of this device, work may be laid out accurately without a jig, as shown in Fig. 56. The head is adjusted vertically and the table crosswise to the hole lowest and farthest to the rear of the jig or other job. Standard $\frac{5}{8}$-in. round-end measures are then used with a 1-in. inside micrometer adjusted to the desired fractional-inch reading. These are inserted in

the troughs provided for this purpose on the column face and the side of the table, sufficiently to correspond with the exact distance to the center of the hole highest and farthest forward in the work.

The measures are held in firm contact with each other and with the hardened abutments on the top of the spindle head and side of the saddle, respectively. The dial indicators are then brought into contact with the opposite end of the string of end measures, their holders clamped to T slots in the trough strips, and the dials rotated to read zero on the indicator pointer.

After the first hole is bored, inside micrometer settings are changed and sufficient end measures are removed to correspond to the exact center distance, vertically and horizontally, to the next hole. The head is raised, and the table is adjusted upward until the remaining strings of end measures again contact the dial indicators; their pointers are brought to the same zero reading. This procedure is continued until all the end measures are removed, and the inside micrometer is adjusted to read zero (but is not removed).

There are some shops that have developed a process in which a variation of this method is employed. The dial-indicator-indexing device is used as before, but in this case, instead of first positioning the spindle with the hole lowest and farthest to the rear, a plug in the spindle taper is brought into contact with locating surfaces in vertical and horizontal planes on the work-holding fixture. To permit the use of stub tools, which are more easily changed than longer through bars, piloted at the rear end, the fixture is reversed 180 deg. by squaring it up with an accurately planed cross slot in the table. Holes in line bored from opposite ends are tested by passing simultaneously a close-fitting arbor through both. This method of inspection guards against possible offset and constitutes a severe test, because any misalignment would be doubled by reversing the job.

This method of indexing has been selected in preference to the use of vernier scales in the machine slides because of the difficulty in reading them at a considerable distance from the operating shafts of the machine, at which point the comparatively heavy slides have to be adjusted to a predetermined vernier reading. This is an entirely different and much more difficult matter than adjusting the vernier head of a caliper to measure a distance already fixed, as for instance, across plugs in bored holes to check

their center distance. The same methods can be applied to jig boring with equally satisfactory results.

A Special Type of Boring Machine.—Many special types of boring machines have been designed and built to suit individual cases. Some of these have far wider applications than those to which they were originally applied. And some, as in Fig. 57, have departed far from conventional lines in design and construction.

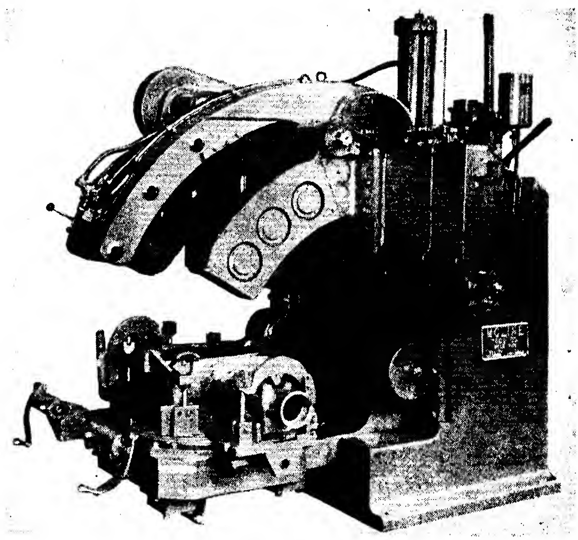


Fig. 57. Unusual type of boring machine.

The machine shown in the illustration is a very unusual type of three-station machine for boring and facing the ends of tractor axle housings and was built by the Moline Tool Company. The work is loaded in the horizontal position shown and is then swung up on the heavy trunnions at the inner end of the fixture and indexed in the three holes seen in the upper or outer arm. Locking bolts on each side of the fixture enter indexing holes and support the work firmly from both sides. Since the distance from the trunnion center to the indexing holes is much greater than that of the boring spindles, there is increased rigidity as well as accuracy in the spacing.

The first two boring spindles both bore and face the ends of the axle while the upper spindle simply sizes the bore. The swinging fixture and its load are handled by a hydraulic cylinder shown at the top of the machine.

Section V

CUTTING TOOLS FOR DIFFERENT MATERIALS

CHAPTER XIX

SINGLE-POINT TOOLS

Tools used in the lathe, planer, shaper, slotter, and boring mill come under the head of single-point tools in the new standardization work of the American Society of Mechanical Engineers. This work will prevent confusion as to terms concerning cutting angles and other parts of the tools. The committee has followed shop practice as to the use of the terms "right-" and "left-" hand tools, even though they are not entirely logical. When in place, a right-hand tool cuts to the left, as in chasing a right-hand thread. Held in the hand, with the cutting point toward the worker, the cutting edge of a right-hand tool is on the right. The definitions of cutting angles, and of the tools themselves, are also given.

Definitions:

1. Each single-point tool comprises a shank and a point (see *A* and *B*, Fig. 1).
   - *a.* The *shank* is that part of the tool on one end of which the point is formed or the tip or bit supported. The shank in turn is supported on the tool post of the machine.
   - *b.* The *point* is all that part of the tool which is shaped to produce the cutting edges and face.
   - *c.* A relatively small point, as required in boring, is sometimes attached to the shank by a neck. The *neck* is an extension of the shank but of reduced sectional area.
2. Single-point tools may be made up in different ways as follows:
   - *a.* The *ground tool* in which a point is formed on the end of a bar (shank) of tool steel by grinding (at *A*, Fig. 1).
   - *b.* The *forged tool* in which a point is forged roughly to shape on the end of a bar (shank) of tool steel and subsequently ground (*B*).
   - *c.* The *tipped tool* in which a tip of tool material, such as high-speed steel, super-high-speed steel, stellite, sintered carbide, or diamond, is welded or brazed to the end of a bar (shank) of steel. It is then subsequently ground to required shape to form the cutting edge and face of the tool.
   - *d.* *Bit tools* in which bits of the tool material, of square, rectangular, or other section, or forged to special shapes, are held in the end of a holder or shank (Fig. 2).

3. *a*. *A right-hand single-point tool.* In looking at the point end of the tool with the face upward, the cutting edge of a right-hand tool is on the right side, at *A*. When used in an engine lathe, the cutting edge is on the left side and it is to be fed into the work to the left, as when cutting a right-hand screw thread.

b. A *left-hand tool* has the cutting edge on the left when looking at the point end with the face upward.

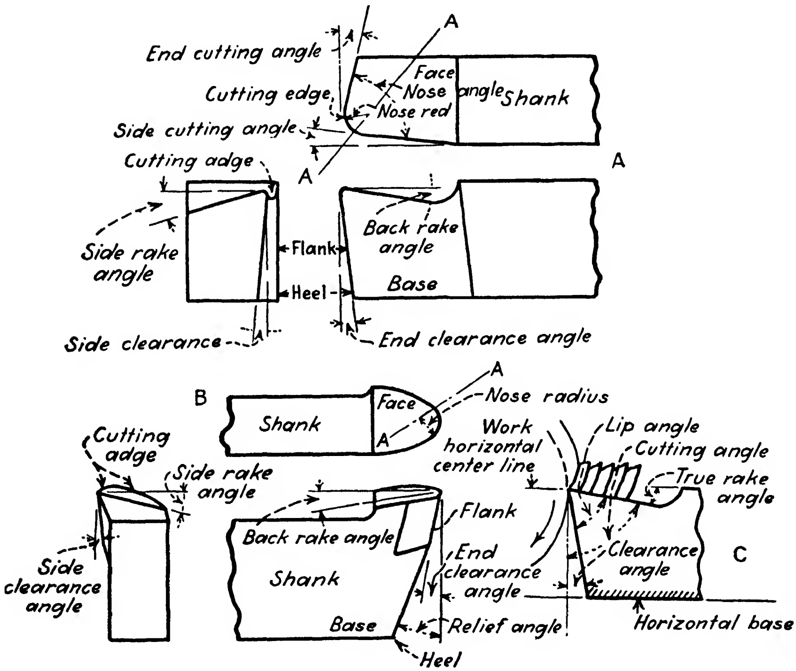


FIG. 1.—*A*, A ground, straight cutting-edge, right-hand, straight-shank, single-point tool with nomenclature; *B*, a forged and ground, curved cutting-edge, right-hand, straight-shank, single-point tool with nomenclature; *C*, section through *A-A* of Figs. *A* and *B*.

4. A single-point tool may be straight, right or left bent, or right or left offset as follows:

a. A *straight-shank tool* has the point on the forward end of a straight shank, at *A*.

b. A *bent-shank tool* has the point bent to the right or left (Fig. 3) to make its operation more convenient. These tools are called right-hand bent-shank tools if the point is bent to the right when looking at the tool from the point end with the face upward.

c. An *offset tool* has the point offset to facilitate the operation (Fig. 4). It is known as a right-hand offset tool if the point is offset

to the right of the shank when looking at the tool from the point end with the face upward.

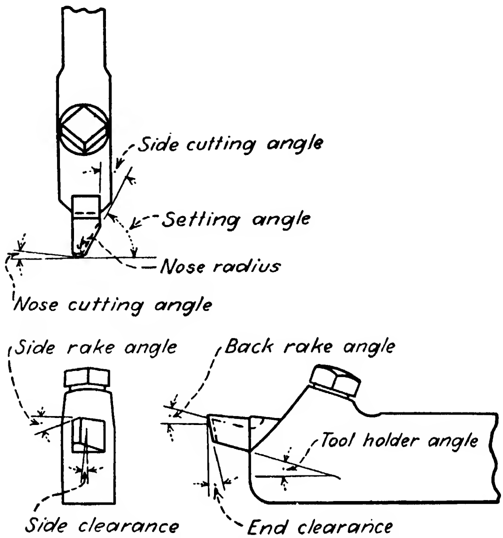


FIG. 2.—A tool bit and holder with nomenclature. The bit should be ground while held in the holder.

5. Each single-point tool consists of *various parts* as illustrated (Fig. 1) in *A*, *B*, and *C*, as follows:

a. The *base* is that side of the shank which bears against the support taking the tangential pressure of the cut.

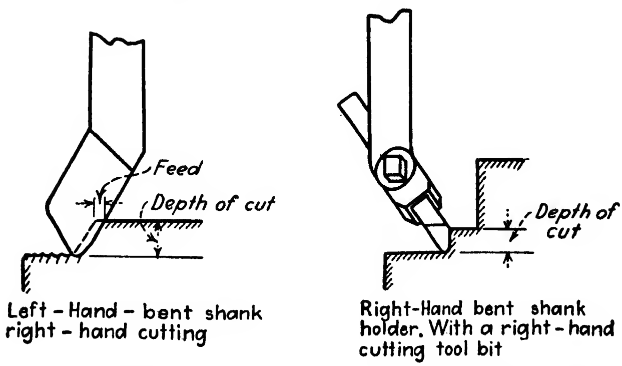


FIG. 3.—Right- and left-hand bent-shank single-point tools.

b. The *face* is that surface on which the chip impinges as it is cut from the work.

c. The *heel* is the forward end of the base immediately below and supporting the face.
d. The *cutting edge* or lip is that portion of the face edge intended to make contact with the material being cut. The cutting edge consists usually of the side-cutting edge, the nose radius, and the end-cutting edge.
e. A *curved cutting-edge tool*, as shown in *B*, has variable side-cutting angles.
f. The *nose* is the curve formed by joining the side- and end-cutting edges.
g. The *profile* is a plan view when looking at the face from a point at right angles to the base. It is formed by joining the side- and end cutting edges with the nose.
h. The *flank* of the tool is the surface below the cutting edge.

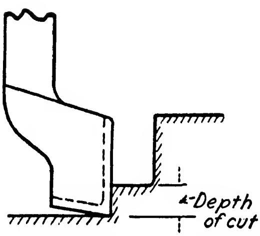


FIG. 4.—Right-hand offset, right-hand cutting, single-point tool.

6. Each tool is provided with *various angles*, as shown in *A*, *B*, and *C*, to facilitate its operation, as follows:

a. *Back-rake angle* is the angle that the face slopes toward the shank of the tool.
b. *Side-rake angle* is the angle that the face slopes to the side at right angles to the axis of the shank.
c. *True rake angle* (or "top" rake), under actual cutting conditions, is the actual slope of the tool face from the active cutting edge in the direction of chip flow. It is a combination of the front- and side-rake angles and varies with the setting of the tool and with the feed and depth of cut.
d. *Clearance angle* is the angle between the ground portion of the flank and the surface being machined.
   (1) *Side clearance* is the angle between the flank under the side-cutting edge and the surface being machined.
   (2) *End clearance* is the angle between the flank at the end and the surface being machined.
e. *Lip angle* is the included angle of the tool material between the face and ground flank measured in a plane at right angles to the active cutting edge.
f. *Cutting angle* is equal to the lip angle plus the clearance angle at the point.
g. *Relief angle* is the angle of the surface below the ground flank, *B*, which is usually forged or rough ground before hardening so as to reduce the amount of grinding on the flank. The flank sometimes extends to the heel (Fig. 1), in which case there is no relief.
h. *Side-cutting angle, A*, is the angle between the straight cutting edge and the side of the tool shank.
i. *End-cutting angle* is the angle between the cutting edge on the end of the tool and a line at right angles to the side edge of the tool

shank (see *A*). As the setting angle is changed, the relation of the end-cutting edge to the work also is changed.

j. *Setting angle* is the angle between the cutting edge and the surface being cut. There are side- and end-setting angles. They are varied by swiveling the tool shank in the machine.

7. The *cutting speed* is the peripheral or surface speed of the work with respect to the tool. In turning it is usually measured on the uncut surface of the work ahead of the tool.

Example: Cutting speed in f.p.m. = 3.1416 × diameter of work in feet × r.p.m.

The extensive use of forged, single-point tools makes the following dimensions, which are suggested by the Midvale Company, of value and interest. These are shown in Fig. 5.

8. The *depth of cut* is the distance that the nose of the tool is buried into the work as measured from the uncut surface ahead of the tool. It equals the thickness of the material being removed from the surface by the tool. In turning it is equal to one half the difference between the original and final diameters.

9. The *feed* is the relative amount of motion of the tool into the work for each revolution or stroke.

10. The *work surface* refers to the surface left by the cutting tool.

Selection of Cutting Tools.—Cutting tools should be selected for their fitness for the work to be done. A recent survey indicated that the various materials were being used in about the following proportions:

Carbon tool steel	15 per cent
High speed, 18-4-1	65 per cent
High speed, 14–4–2	11 per cent
Cobalt high-speed steel	4 per cent
Stellite	3 per cent
Tungsten and tantalum carbide	2 per cent

The designation of the high-speed steels refers to the percentage of tungsten, chromium and vanadium, respectively.

Carbon steel still has its place in machining soft materials and for finishing cuts where the metal is not too hard. Many feel that it can give a smoother finish than high-speed steel. It is in wide use for wood-working tools.

High-speed steel is widely used as indicated in the table. The cobalt steel is frequently known as super- high-speed steel. Stellite is often used on hard metals such as cast iron of thin section, and on other metals. These tools should be well supported as the edge is somewhat brittle. Sintered carbide tools, known under various trade names and consisting of

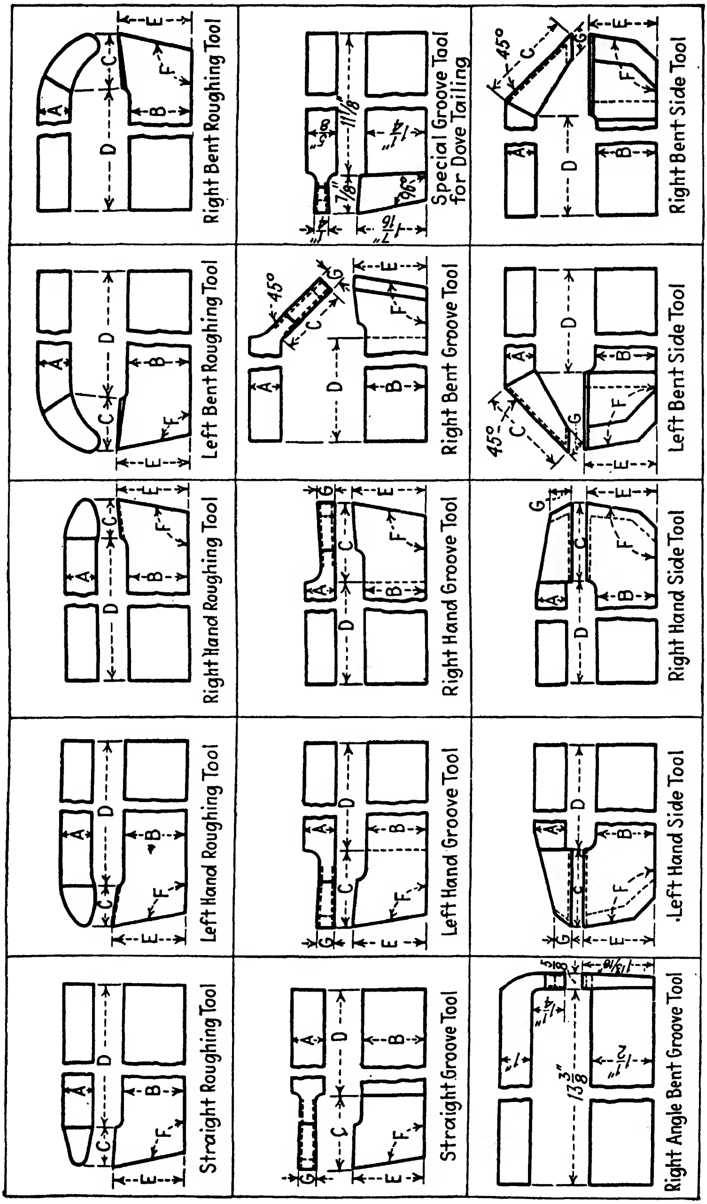
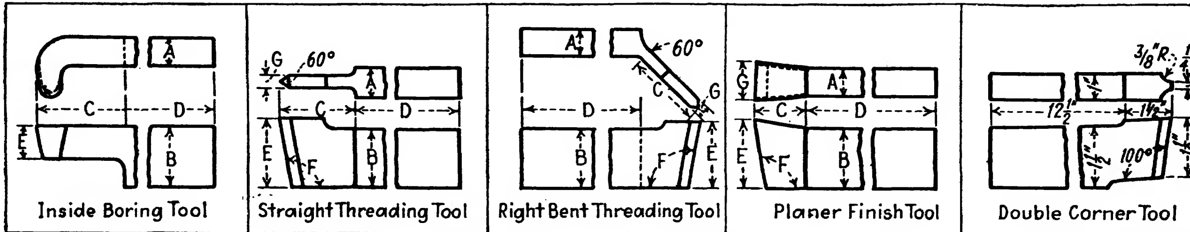
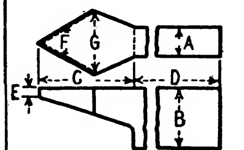


FIG. 5.—Sizes of forged tools. Right and left hand bends as shown. are the old definitions. Correct names of bends shown at 4*b* page 392.



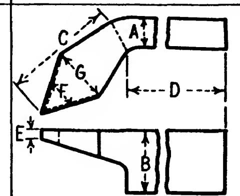


Roughing Tools

A	B	C	D	E	F	G
1"	1½"	1⅛"	12⅛"	1 11/16"	98°	
5/8"	1¼"	¾"	11¼"	1 7/16"	"	
½"	1"	5/8"	8⅜"	1 3/16"	"	

Right, Left and Right Bent Groove Tools

A	B	C	D	E	F	G
1"	1½"	1¾"	12¼"	1 11/16"	96°	3/8"
5/8"	1¼"	1½"	10½"	1 7/16"	"	¼"
½"	1"	1¼"	7¾"	1 3/16"	"	3/16



Centering Tools

A	B	C	D	E	F	G
1"	1½"	3½"	12½"	¼"	60°	1⅛
5/8"	1¼"	3"	10"	3/16"	"	1⅛
½"	1"	2½"	8"	⅛"	"	1"

Side Tools

A	B	C	D	E	F	G
1"	1½"	1¾"	12¼"	1 11/16"	100°	5/8"
5/8"	1¼"	1½"	10½"	1 7/16"	"	3/8
½"	1"	1¼"	7¾"	1 3/16"	"	5/16

Planer Finish Tools

A	B	C	D	E	F	G
1"	1½"	1¾"	12¼"	1 11/16	96°	1⅛
5/8"	1¼"	1½"	10½"	1 7/16"	"	¾"
½	1"	1¼"	7¾"	1 3/16"	"	5/8

Boring Tools

A	B	C	D	E	F	G
1"	1½"	4½"	12"	1"		
5/8"	1¼"	4"	10"	5/8"		
½"	1"	3½"	8"	½"		

Threading Tools

A	B	C	D	E	F	G
1"	1½"	1¾"	12¼	1 11/16	105°	9/16
5/8"	1¼"	1½"	10½"	1 7/16	"	7/16
½"	1"	1¼"	7¾"	1 3/16"	"	5/16

Straight Groove Tools

A	B	C	D	E	F	G
1"	1½"	1¾"	12¼"	1 11/16	96°	⅞"
5/8"	1¼"	1½"	10½"	1 7/16"	"	9/16

FIG. 5.—*Continued.*

tungsten or tantalum carbides, are the hardest known cutting tools except the diamond. They are expensive and are used only in the form of tips brazed to high-speed or carbon-steel shanks, or with tipped blades in an inserted tooth-milling cutter. They are very good on hard materials and permit high cutting speeds. The feed should be light and it is not advisable to take a very deep cut. In most cases, intermittent cuts are avoided with these tools. The following comparisons of cutting speeds in feet per minute are given by R. R. Weddell in Table I.

TABLE I.—CUTTING SPEEDS OF VARIOUS TOOLS

Material cut	H.S.S.	Super-cobalt H.S.S.	J Stellite	Tungsten carbide
Cast iron	90	120	150	250
Steel castings	75	100	x	x
Machine steel	100	125	x	x
Alloy steel	75	100	x	x
Bronze	100	125	150	250
Brass	250	300	400	500
Copper	250	300	400	500
Aluminum	800	1,000	1,000	1,500

For our purpose, the important characteristics of high-speed steels may be divided into three principal types, each having definite compositions and properties:

Properties of High-speed Steels: *High-tungsten High-speed Steel.*—The high-tungsten, low-vanadium type is generally known as 18-4-1 high-speed steel, the numbers indicating its tungsten, chromium, and vanadium content by percentages. Its analysis is approximately 0.70 per cent carbon, 18 per cent tungsten, 4 per cent chromium, 1 per cent vanadium, manganese under 0.30 per cent, silicon under 0.35 per cent, phosphorus and sulphur under 0.03 per cent.

This is a general-purpose tool steel. Because of its inherent ability to stand up under abuse, because of its great resistance to wear and of its marked cutting properties, this type of high-speed steel has found a very wide field of application. Its wide hardening range, 2275° to 2375°F., together with its ability to resist scaling or decarburization at these hardening tempera-

tures, aids greatly in minimizing failures due to faulty heat treatment. Its hardness will be approximately the same whether air-cooled or quenched in oil, molten-salt-lead baths. In other words, it has the property of so-called "air hardening." After tempering from one to four hours at 1050° to 1125°F., it will have a Rockwell "C" hardness of 62 to 65.

Low-tungsten High-speed Steel.—The low-tungsten, high-vanadium type of high-speed steel has a chemical analysis approximately identical with the 18-4-1 steel, except for its tungsten and vanadium content. These constituents are: tungsten 14 to 16 per cent, vanadium approximately 2 per cent.

This steel has a much narrower hardening range than the 18-4-1 type and should be hardened as close to 2300°F. as possible. After tempering, it should have a Rockwell "C" hardness of 62 to 65. Its chief use has been for lathe and planer tools for cutting rather hard and tough materials. When properly hardened and tempered, this steel will make excellent cutting tools.

Super- or Cobalt High-speed Steels.—When from 3 to 12 per cent of cobalt is added to either the No. 1 or No. 2 analyses above, we have what is known as super- or cobalt high-speed steels. In order to get the beneficial effects of the cobalt, it is necessary to harden these steels at temperatures about 100°F. higher than would be used if cobalt were not present.

Cobalt steels are very susceptible to decarburization at these high temperatures. It is, therefore, necessary to grind considerable material from all cutting or wearing surfaces after hardening, in order to remove soft skin or surface due to this decarburization.

Much has been claimed for cobalt steels, mainly because of their ability to cut Hadfield's 12 per cent manganese steel. This material cannot be successfully machined with tools made from 18-4-1 high-speed steel. However, this is a special application for which the cobalt steels are particularly suited. On the other hand, there are many other applications where the other two types of steels are making records that cannot be equalled by the cobalt steels.

All of the above high-speed steels have been thoroughly investigated by competent chemists, metallurgists, and engineers in all parts of the world. Their physical and chemical properties

are definitely established, and can be controlled accurately throughout the various manufacturing processes. In order to select or design proper tools for any given metal-cutting operation, it is equally important that we know the characteristics of the material to be cut, the operating condition of the machine, and other characteristics of any given set-up. Only by proper coordination of all the factors enumerated can the best results be obtained.

BILL OF MATERIAL

Item	Name	Size, In.	Material	Req.	Co. Unit Item No.	Stock Item No.
1	Tip	5/8" x 1 1/4" x 2 1/2" long	No.16-T.S.	1		107-P-K
2	Shank	1 1/2" x 1 1/2" x 12" long	No.1-T.S.	1	1 and 2	6439.12
3	Shank	1 1/2" x 1 1/2" x 9" long	No.1-T.S.	1	1 and 3	6439.9
4	Shank	1 1/2" x 1 1/2" x 7" long	No.1-T.S.	1	1 and 4	6439.7

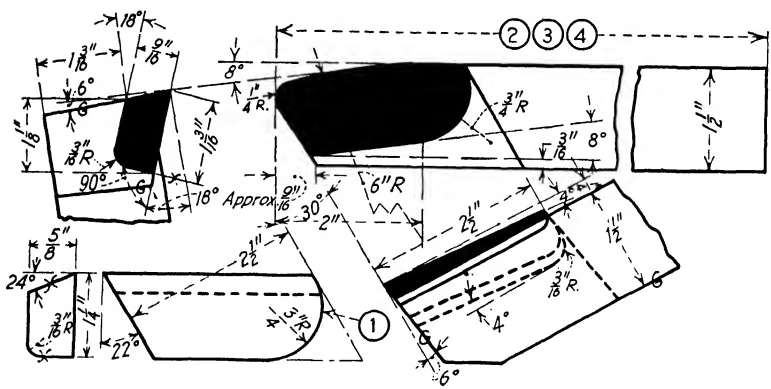


FIG. 6.—This shows the size of both tip and shank and gives the angles used.

Super-high-speed Steel.—High-speed steel in which cobalt is used is becoming known as "super-high-speed" steel to distinguish it from steel using tungsten and other alloys. This material is being used for tipping lathe, planer, and shaper tools, etc. In deciding on the kind of tools to be forged or tipped, the experience of J. M. Highducheck, assistant superintendent of the Westinghouse Electric & Mfg. Co., is of great value. Table II shows the shank sizes of the tools he uses. Only tools used at high cutting speeds should be tipped. Standard high-speed steel is sufficient for all other tools.

Tools should not be tipped unless the mean cross section of the shank is at least 7/8 in. Details of the method of tipping are shown in Fig. 6. Tipped tools should be so designed as

TABLE II.—SHANK SIZES OF HIGH-SPEED TOOLS

Lathe, shaper, planer								Boring mill							
Size	Shank length			Size	Shank length			Size	Shank length			Size	Shank length		
1/4 × 3/8	5	4		1 × 2	20	16	12	1/4 × 1/4	2 1/2			1 1/4 × 1 1/4	9	7	5
5/16 × 1/2	6	5		1 1/4 × 2 1/4	22	18	14	3/8 × 3/8	3			1 1/2 × 1 1/2	12	9	7
3/8 × 3/4	7	6		1 1/2 × 2 1/2	24	20	16	1/2 × 1/2	4			1 3/4 × 1 3/4	16	12	9
1/2 × 1	8	6		3/4 × 1	5	6	7	5/8 × 5/8	4 1/2			2 × 2	20	16	12
5/8 × 1 1/4	10	8	6	3/4 × 2	20	16	12	3/4 × 3/4	5						
3/4 × 1 1/2	12	10	8					1 × 1	7	5					

TABLE III.—AVERAGE CUTTING SPEEDS AND FEEDS FOR TURNING, FACING, AND BORING WITH STELLITE J-METAL

Material	Hard cast iron		Medium cast iron		Bronze		Malleable iron		Steel castings		S.A.E. 3115		Cold rolled stock	
Type of cut	Cutting speed, ft. per min.	Feed per rev., in.	Cutting speed, ft. per min.	Feed per rev., in	Cutting speed, ft. per min.	Feed per rev., in.	Cutting speed, ft. per min.	Feed per rev., in.	Cutting speed, ft. per min.	Feed per rev., in.	Cutting speed, ft. per min.	Feed per rev., in.	Cutting speed, ft. per min.	Feed per rev., in.
Rough turn...	100	0.035	125	0.050	219	0.035	188	0.035	125	0.025	180	0.033	344	0.033
Finish turn...	163	0.035	188	0.050	313	0.025	281	0.035	300	0.018	331	0.015	488	0.015
Rough face...	100	0.035	125	0.050	219	0.035	188	0.035	125	0.025	180	0.033	344	0.033
Finish face....	163	0.035	188	0.050	313	0.025	281	0.035	300	0.018	331	0.015	488	0.015
Rough bore...	88	0.035	100	0.050	219	0.035	156	0.035	113	0.025	163	0.025	300	0.025
Finish bore...	163	0.035	188	0.050	313	0.025	281	0.035	300	0.018	250	0.015	375	0.015

NOTE: Cutting speeds and feeds on cast iron may be increased if a coolant is used. Use water and sufficient soluble oil to prevent rusting of work.

Average Cutting Speeds for Milling Cast Iron or Semi-steel

Rough milling
- Line-type machine........ 100–120 ft. per minute
- Drum-type machine........ 120–140 ft. per minute

Rough and finish milling—one cut
- Line-type machine........ 125–140 ft. per minute
- Drum-type machine........ 140–160 ft. per minute

For finish milling best results are obtained at........ 175–200 ft. per minute

Haynes stellite is also used for milling malleable iron, mild steel, bronze, steel castings, hard rubber and fiber.

The speeds and feeds shown in these charts are conservative and represent average practice on production jobs. The speed and feed of a job are governed by the structure and hardness of the part machined, amount of metal removed, and the condition of the machine and fixtures. Therefore, the figures cannot be accepted as applicable to every job but will serve as a starting point.

to require only a minimum of grinding. Avoid the necessity for forging tips if possible; use steel from stock by cutting to length. The tip should be machined rather than ground, if this is necessary.

Cobalt steels should not have more than 6-deg. side clearance and from 16- to 18-deg. cutting angle. Carbon steel can be used for shanks, when tips only are used.

Stellite Tools.—The Haynes Stellite Company recommends the cutting speed and feed for their J-Metal as given in Table III. These data are conservative and represent average practice on production jobs. While not applicable to every job, they serve as a starting point in trying out a new job. Cutting speeds on cast iron can be increased if a coolant is used. Water and sufficient soluble oil to prevent rusting will be found satisfactory. Table IV gives details of several actual operations.

TABLE IV.—CUTTING DATA WITH STELLITE TOOLS

Part	Material	Operation	Cutting speed, f.p.m.	Depth of cut	Feed in. per rev.	Coolant
Bushing	Cast steel	Rough turn	80–100	3/16–3/8	0.033	No
Bushing	Cast steel	Rough turn	72	3/16	0.068	Yes
Flywheel	Cast iron	Rough turn	71	3/16	0.032	No
Flywheel	Cast iron	Finish	110	1/32	0.015	No
70-in. wheel	Cast iron	Turn	75	1/8 –1/2	0.085	No
Pistons	Cast iron	Turn	257	1/16–3/32	0.038	No
Camshafts	1040*	Turn	220	1/16	0.032	No
Brake drums	1025*	Turn	454	1/64	0.005	No
Brake drums	1025*	Turn	440	1/32	0.014	No
Ring gear	2115*	Turn	125	1/16	0.020	Yes
Gear, blank	3135*	Turn	100	3/16	0.033	Yes
Trans. gear	6150*	Turn	75–90	1/16–1/8	0.020	Yes
Stainless steel	....	Turn	280	1/8	0.012	Yes
Heat-treated steel	....	Turn	85	1/4	0.046	Yes
Tire steel loco	....	Turn	91	1/8	0.063	No

* These numbers indicate the grades of SAE steels used.

Stellite tools should be ground differently from steel tools. The difference is simple to understand. The edge strength of Stellite is not so great as steel and the cutting edge must have more support.

Proper wheels should be selected for grinding Stellite. Below is a list of recommended wheels.

HAND GRINDING

Carborundum........................46N Aloxite Vitrified
Detroit star........................46M Staralox Vitrified
Norton........................46M Alundum Vitrified
Precision................................46M Vitrified
Sterling................................46M Vitrified

MACHINE GRINDING

Carborundum........................46P Aloxite Vitrified
Detroit star........................46J Staralox Vitrified
Norton........................1946J Alundum Vitrified
Precision................................46J Vitrified
Sterling................................46J Vitrified

Other makes of wheels may be used, but these are given as a guide in selecting grade and grain. Any soft-grade vitrified wheel, not coarser than 46 or finer than 60 in grade I or J is excellent for grinding Stellite. The new diamond abrasive wheels are good for finishing.

Preferred speeds of wheels for grinding Stellite should not be less than 2,500 surface ft. per minute or more than 4,200 ft. per minute. Higher speeds than the maximum given above will probably check the work.

CHAPTER XX

SINTERED-CARBIDE TOOLS

Carbide cutting tools have made a place for themselves in nearly all classes of machine work. Although not particularly successful at first in the cutting of steel owing to the failure of the cutting edges under heavy pressure, carbides are now used almost exclusively on even the harder and tougher alloys, such as armor plate, where production is essential. They are also being used on many older machines that do not have the necessary speed or power to secure maximum results, because of their longer life between grinds, and in this way cutting down the time lost because of stoppage for grinding or changing tools.

Although usually called "cemented" carbide this is really a misnomer as they are "sintered" instead of cemented, and should be called "sintered carbide."

The first of these alloys was called Widia, meaning "like a diamond" in German, as the first of these tools came from the Krupp works in Essen, Germany, and were introduced here by the Thomas Prosser Company. Under license from Krupp, the General Electric Company brought out Carboloy, which was followed by a number of other trade names such as Firthite, Kennametal, Vascaloy-Ramet, Tan-Tung, and others. All have been greatly improved and the cost has been reduced to a marked degree. No matter which of the carbides it is decided to use, it is advisable to consult the makers of that particular brand as to their suggestions regarding its use.

General Recommendations.—The following suggestions, given originally for Widia tools, are still worthy of attention for those using carbides for the first time:

Eliminate all vibration from the machine, including the tool-holding devices and the tool slides.

Support the tool as rigidly as possible at the front end of the tool shank, with as little overhang as possible.

Avoid stalling the machine with the tool in a cut. Should

stalling occur, disconnect the feed, loosen the clamp screws, and remove the tool as carefully as possible. Examine the tool carefully before using it again.

To stop a cut, first throw out the feed to allow the tool to clear itself, before stopping the machine.

Set turning tools slightly above center and boring tools at the center. Use high speeds and light feeds in almost all cases. Do not let tools get dull.

Cutting angles vary with the material to be cut and the nature of the work. On very hard material, such as armor plate, it has been found best to use a negative rake instead of the usual positive-rake angles. This is particularly true in turning interrupted cuts. With the negative rake, the first contact with the work is behind the point where the carbide tip is better supported.

Tool angles for average work are suggested in Table V.

TABLE V.—SUGGESTED TOOL ANGLES

Material	Front relief, deg.	Side relief, deg.	Side-rake angle, deg.	Nose radius, in.
Cast iron.........	6	4	12	$\frac{3}{8}$ to $1\frac{1}{4}$
Soft steel.........	6	6	14	$\frac{3}{8}$ to $1\frac{1}{4}$
Medium steel.....	6	6	14	$\frac{3}{8}$ to $1\frac{1}{4}$
Hard steel........	4	4	14	$\frac{3}{8}$ to $1\frac{1}{4}$
Nonferrous.......	6	6	Negative	

As mentioned before, high speeds and light feeds are best with carbide tools. Table VI is suggested by John C. Coonley, tool superintendent, and J. H. Howieson, time-study manager of the Walworth Company, as a result of their own experience. Higher or lower speeds may be found best in some cases, depending on the materials, the machines, and other conditions. On short lots where the tools are to be reground before being returned to the tool crib, it often pays to use higher speeds, which shorten the tool life but still do not necessitate changing the tools during the run.

Tool shapes vary with the material to be cut and also the ideas of the production department. The shapes originally recommended for Widia tools are useful as guides. As shown in Fig. 7 they show both roughing and finishing tools. The illustrations

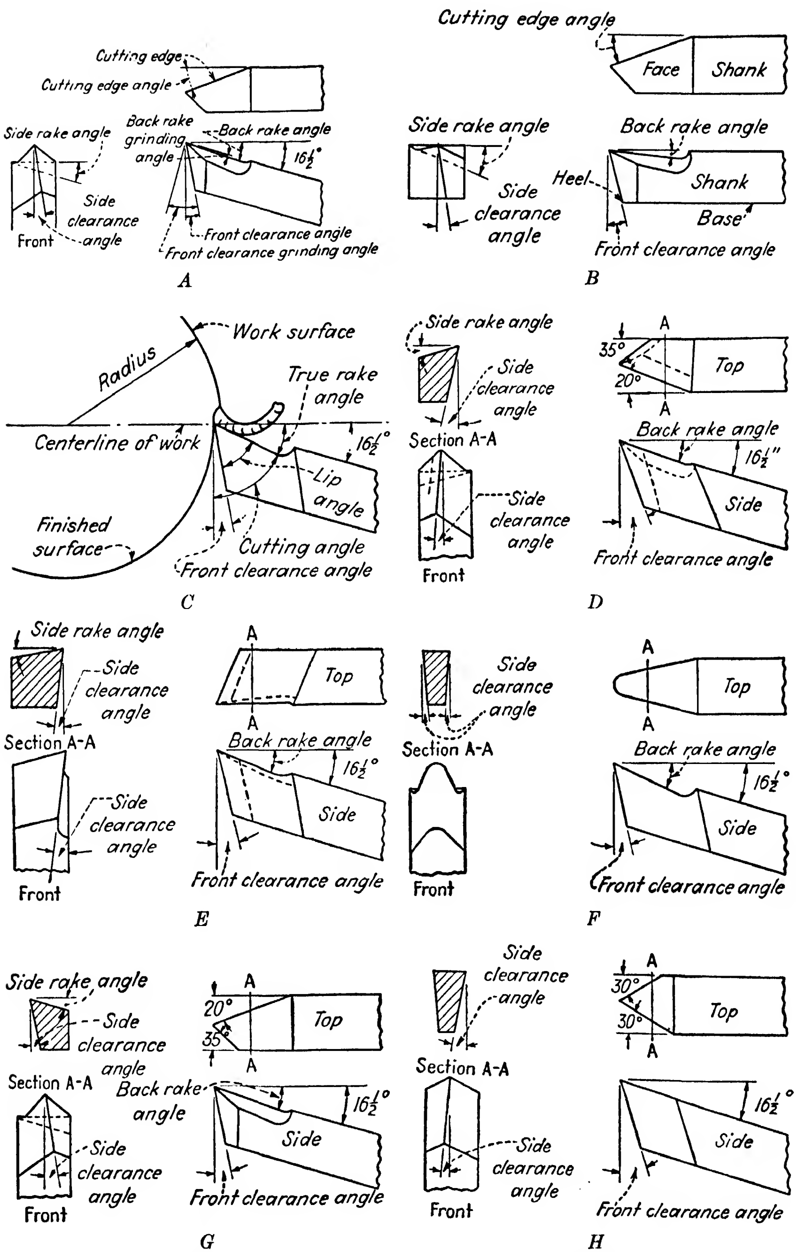


FIG. 7.—Shapes for tool bits to fit tool holders.

are rather complete and make a fair guide to the general use of these tools. Other tools shapes, to be used in tool bits that fit into tool holders, are shown in Figs. 7*A* to 7*H*. The official A.S.M.E. designations are used for the tool angles.

TABLE VI.—SUGGESTED SPEEDS, FEEDS, AND CUTS

Operation	Surface speed, ft. per min.	Feed, in. per revolution	Depth of cut, in.	Pieces per grind
Machining 500 Brinell 18 chrome, 0.90 steel	350	0.002	0.008, two cuts	100
Facing carbon molybdenum steel castings	100	0.032	1/8–1/4	25
Machining monel metal valve yokes	150	0.012	3/32	60
Facing and turning bronze gate valve wedges	700	0.004	1/32	1,000
Turning and facing stainless gate valve wedges	80	0.012	3/16	50

Figure 8 shows an unusual but very useful method of adjusting the height of the tool. A wedge block and a link chain with a corresponding taper make it easy to secure accurate adjustment of the height. The gage shown is also a convenience in setting the tool.

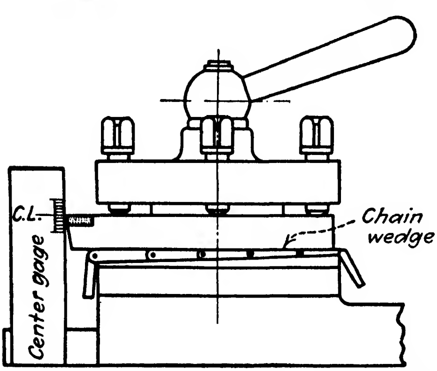


FIG. 8.—A suggested method of adjusting tool for height and a simple center gage.

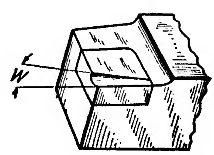


FIG. 9.—Width of chip breaker.

Figure 9 shows the type of chip breaker advised by the Carboloy Company for use in high-speed turning with Carboloy tungsten-carbide tools. This prevents the turning of long chips which get in the way and may even be dangerous at times, due partly to the high speed possible with carbide. Table VII

shows the recommended width of the chip breaker for different feeds. A depth of 0.020 in. is usually sufficient. It should be parallel with the face of the tool so as not to present a sharp and easily broken corner to the work.

TABLE VII.—WIDTH OF CHIP KENNAMETAL BREAKERS (SEE FIGS. 12, 13 AND 14)

Depth of cut, in.	Feed, in. per revolution				
	0.008–0.012	0.013–0.017	0.018–0.022	0.023–0.027	0.028–0.035
	Width of chip breaker, *W*, Fig. 9				
1/64–3/64	1/16	5/64	3/32	7/64	1/8
1/16–1/4	3/32	1/8	5/32	11/64	3/16
5/16–1/2	1/8	5/32	3/16	13/64	7/32
9/16–3/4	5/32	3/16	7/32	15/64	1/4

Chip Breakers and Chip Curlers.—There are differences of opinion regarding the use of chip breakers. This is particularly true in turning hard, tough material such as armor plate. With

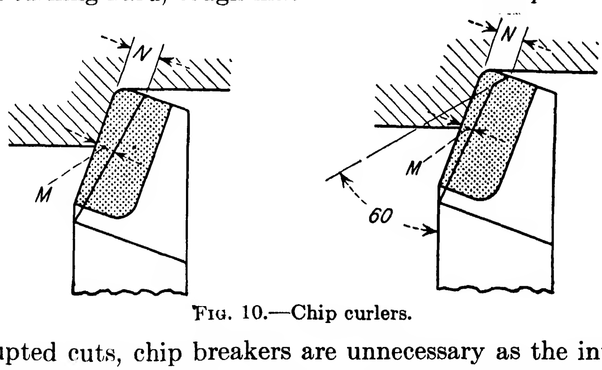


FIG. 10.—Chip curlers.

interrupted cuts, chip breakers are unnecessary as the interruptions will break the chips. Some feel that chip breakers reduce tool life by increasing the tool pressure on top of the cutting edge. They prefer what they term "chip curlers" which resemble the breakers very closely, as will be seen from Figs. 9 and 10. They evidently refer to chip breakers that are clamped to the top of the tool behind the cutting edge.

These illustrations show width of the curler at *N* to be 1½ times the width at *M*, which is at the surface of the work. Two types of chip curler are seen in Fig. 10. In one the end next the work is

ground at 60 deg. from the tool shank or 30 deg. from the axis of the work. The distance N is also about $1\frac{1}{2}$ times the nose radius.

Deep cuts and light feed are best for tough materials, whether the cut is interrupted or not. If the tool strikes a sand pocket or hard inclusion, it is usually deep enough in the metal so that the nose is in clean metal, it being best to have more than the nose radius buried in the cut. It should also be remembered that the side-cutting angle affects the actual thickness of the chip being removed. It will be seen that the actual chip thickness decreases as the angle increases. This is shown in Table VIII. This shows that the larger the side angle on the tool the larger the feed should be to ensure a chip thick enough to prevent abrasion by merely scraping the surface.

TABLE VIII.—ACTUAL CHIP THICKNESS

Side-cutting angle, deg.	Feeds, in.	
	0.010	0.015
	Actual chip thickness for different feeds	
0	0.0100	0.0150
15	0.0097	0.0145
30	0.0086	0.0130
45	0.0071	0.0106
60	0.0050	0.0075

If a coolant is used, it should be directed against the work rather than the tool and cool it in this way if possible. If not, use a high-pressure stream directly against the tool with plenty of volume. Soluble oils are recommended.

Kennametal Tools and Chip Breakers.—A standard turning tool recommended by Kennametal is shown in Fig. 11 and the various angle designations are made very clear. These are standard definitions.

Three types of chip breakers are shown in Figs. 12 to 14, together with recommendations as to dimensions. These should be followed for best results, as they are the result of many

TABLE IX.—GRINDING WHEEL RECOMMENDATIONS

Wheel elements	Offhand grinding				Machine grinding	
	Roughing wheels		Finishing wheels		Roughing wheels	Finishing wheels
Type of abrasive	Silicon carbide	Diamond	Silicon carbide	Diamond	Diamond	Diamond
Grit size	60	100	100	220	100	180
Type of bond	Vitrified	Resinoid	Vitrified	Resinoid	Resinoid	Resinoid
Grade	Medium	Soft to medium	Medium	Soft to medium	Soft to medium	Soft to medium
Structure	Medium	.....	Medium			
Concentration	.....	Low	.....	Medium	High	High
Shape of wheel	Cup or straight	Cup	Cup	Cup	Straight	Straight
Manufacturers' wheel markings						
Norton*	37C60-17-V (grey grit) 39C60-17-V (green grit)†	D100-J25-B	37C100-17-V (grey grit) 39C100-17-V (green grit)†	D220-J50-B	D100-J100 B	D180-J100-B
Carborundum*	HC60-17-VW (grey grit) GC60-17-VW (green grit)†	D100-L25-B	HC100-17-VW (grey grit) GC100-17-VW (green grit†)	D220-L50-B	D100-L100-B	D180-L100-B

* Other manufacturers can supply equivalent abrasive wheels.

† Green grit preferred, when obtainable.

Wheel speeds: Best results are obtained with a peripheral speed of 5,000 to 5,500 feet per minute on straight wheels, and 4,300 to 4,700 on cup wheels.

Wheel rotation: The direction of rotation always should be downward so that grinding force of wheel tends to press carbide tip against shank.

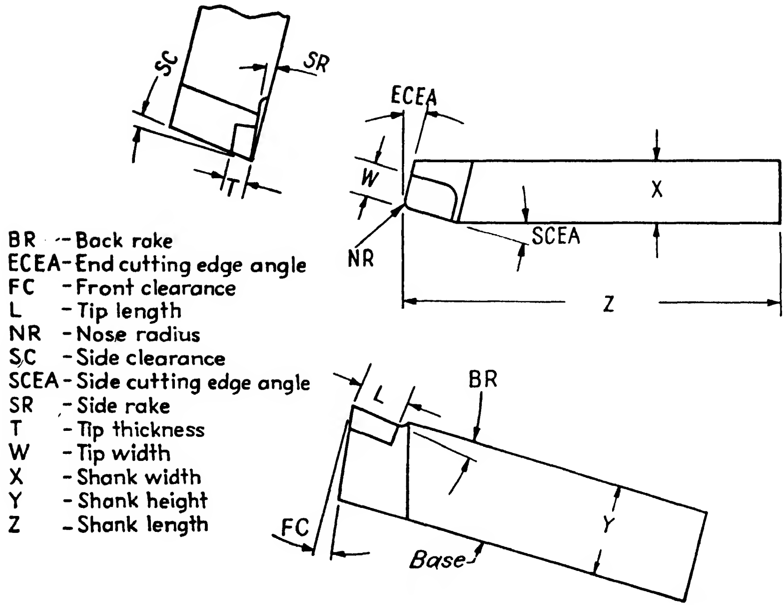


FIG. 11.—Standard Kennametal tool.

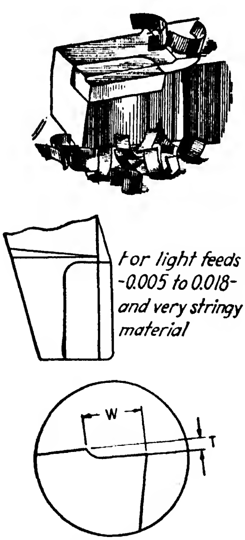


FIG. 12.—Chip breaker for light feeds.

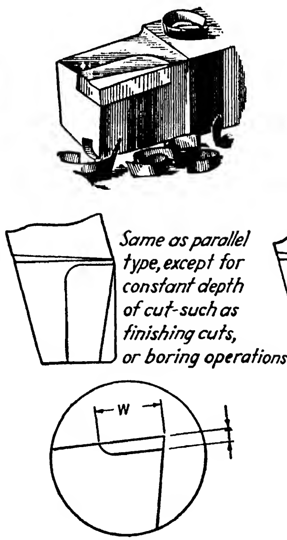


FIG. 13.—Chip breaker for finishing cuts and boring tools.

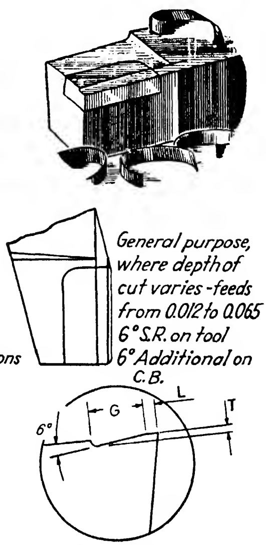


FIG. 14.—General purpose chip breaker.

experimental tests with turning tools. Dimensions and data are also given.

Tool Wear and Tool Grinding.—Careful inspection of dull tools in connection with the following illustrations and tables will give the suggestions of Kennametal for securing better results from the use of carbide tools. Figures 15 and 16 can be very helpful, especiallv if Table VI is consulted as to the cutting speeds to be used.

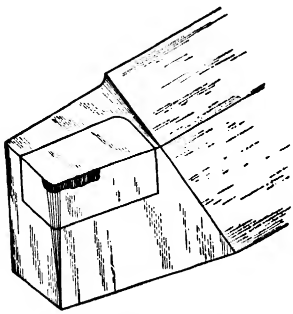


Fig. 15.—Excessive edge wear.

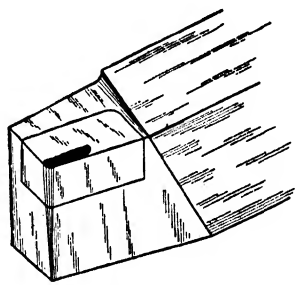


Fig. 16.—Excessive tap wear.

Having determined the reasons for excessive wear or cratering, note the suggestions in Table IX as to the proper grinding wheels to use. This also gives the direction in which the wheel should run when grinding and the wheel speeds for both straight and cup wheels.

Tables XI to XVI inclusive are valuable in selecting speeds, feeds, and depth of cut for a variety of materials. These tables are very complete and give speed ranges to cover many operations.

HOW SINTERED-CARBIDE CUTTING TOOLS ARE MADE*

Sintered carbide includes all the various tools made by compacting minutely divided particles of cobalt, tungsten, tantalum, or other carbides by hydraulic pressure and sintering them into a briquette in a reducing atmosphere far below that necessary for the fusion of the metals. In the beginning there were many failures due to the tip separating from the shank, abrasion, spalling, or crumbling of the cutting edge, cracks and pits

* By Malcolm F. Judkins, Chief engineer, Firthite division; William C. Uecker, Engineering Department, Firth-Sterling Steel Company.

Experience has shown that there are ten points to be considered for best results with these tools. They are

1. Method of attaching the tip to the shank.
2. Tip and shank size.
3. Cutting-edge contour.
4. Tip and shank shape.
5. Preparation of the cutting edge.
6. Tool angles.
7. Tool setting.
8. Tool block or holder and the work fixtures.
9. Selection of proper speeds, feeds, and cuts.
10. Selection of a cutting fluid.

Attaching Tips.—While welding is perfectly satisfactory in attaching tips of high-speed steel to shanks of less expensive metal, copper brazing in an electrically heated hydrogen atmosphere furnace is best for carbide tips. Pure copper is used because it is tough and ductile, holding the tip and having elasticity enough to protect the tip from the contraction forces due to cooling from the brazing temperature of 2,050°F. The comparatively high melting point of copper prevents it from squeezing out under heavy cutting pressure and the high temperatures resulting from roughing cuts. The tip is hand-ground to fit the recess in the shank. Both shank and tip are thoroughly cleaned in hot sodium hydroxide solution and then rinsed in clean water and dried. The shank recess is sprinkled lightly with borax or other flux and copper foil of 0.003 to 0.005 in. placed under the tip, which is wired in place with nichrome wire. It is heated until the copper starts to flow, then moved to a cooling chamber. Silver solder, brass, or bronze can be used.

Both tip and shank should be as large as cost will permit. The tip should be thick but need be no longer than necessary. The shank should be as deep as the tool post will take. The shank should be at least one and one-half times as deep as the shank of the high-speed or other steel tool which the carbide tool replaces.

Cutting-edge Contour.—When cutting a ductile material, such as steel, the cutting edge which will give the least amount of chip distortion should be chosen. Energy expended in unnecessary chip deformation is wasted and needlessly imposes excessive chip loads on the cutting tool.

The nose radius for light cuts should be as small as practicable, and wherever possible the angle which the cutting edge makes with the work should be less than 90 deg. In Fig. 17, it is obvious that, while both tools may take the same depth of cut and feed per revolution and operate under the same cutting speed, the tool shown at *A* will be the more durable, since each portion of its cutting edge has less to do than corresponding portions of the cutting edge of tool *B*. This is especially important in cutting a hard, abrasive material which is destructive of the cutting edge such as chilled rolls.

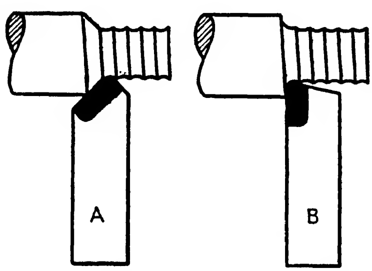


Fig. 17.—Concentration of the chip pressure is avoided by the design at *A*.

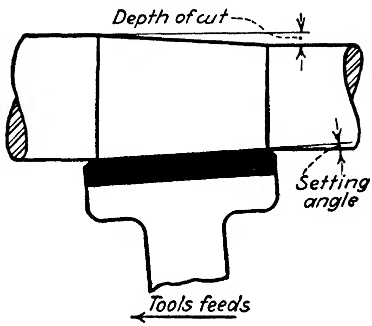


Fig. 18.—For roll turning, a wide tool set at a slight angle has proved effective.

In roll cutting, it was usual to employ a tool with a straight cutting edge, frequently 6 or more inches in length, which was fed by hand straight in to the desired depth. New roll-turning lathes are equipped to feed such tools laterally or parallel to the axis of the work as in an ordinary engine lathe. In this case, as shown in Fig. 18, the tool is set at a slight angle which produces just the desired depth of cut in little less than the length of the cutting edge.

Wear Greatest at Corners.—For certain types of light finish cuts, the cutting edge is best chamfered at 45 deg. as shown in Fig. 19 at *A*. Care should be taken, however, to insure that the extent of the chamfer will accommodate the full depth of cut, or else the badly deformed type of chip shown at *B* will result. The corners should be rounded slightly or just broken as shown, because experience teaches that wear will be most pronounced where the cutting-edge contour changes direction abruptly.

This point is well emphasized in Fig. 20, which shows the actual measured distribution of wear on the flank of an inserted milling cutter blade after face milling gray cast iron to a point arbitrarily selected as corresponding to the amount of wear permissible before regrinding.

For roughing cuts, the familiar Taylor round nose accomplishes somewhat the same purpose, since the chip is spread over a greater length of cutting than in the case of a straight 90-deg.

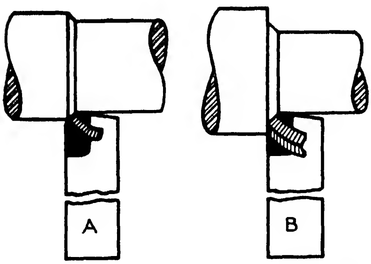


Fig. 19.—A 45-deg. cutting edge is satisfactory for finishing cuts but should be long enough to take the full depth as at *A*.

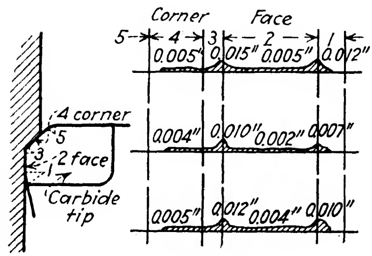


Fig. 20.—Measured wear on milling cutter teeth, selected at random, is greatest at abrupt changes in contour.

setting angle bar turning or knife tool. The round-nose tool also tends to prevent chatter for the reason that the chip thickness is variable.

Tip and Shank Shape.—The shape of the tip must be selected after a proper balance has been struck among several factors. The tip must be shaped and located in the shank recess, which receives it, to provide adequate support to withstand the forces developed in cutting. This means that the tip must have a broad, smooth base on which to rest, that there must be sufficient shank metal beneath and beside the tip to absorb the tangential and feeding pressure without deflection, and that the bulk of the forces to which the tip is subjected must be transmitted to the steel shank.

Tool Angles.—Tool angles may be divided into three main groups:

1. Setting angles or angles the cutting edges make with the work axes.
2. Clearance angles.
3. Rake angles.

As previously mentioned, considerable gain in tool life can

be made with acute setting angles. Frequently, the conditions imposed by the nature of the operation prohibit their use. Wherever possible they should be used.

The clearance angles should be as great as, but no greater than, will produce a free cutting action. In general, 4 to 6 deg. is sufficient, but for some soft metals and for most nonmetallic substances, rather large clearance angles are not only necessary but desirable.

Rake adds keenness to the cutting edge, gives freedom for the removal of chips, reduces the feeding and radial pressure, and for ductile metals, such as steel, materially reduces the extent to which the metal preceding the cutting edge is work-hardened. For soft, stringy metals, such as aluminum, drastic rakes are necessary in order to get a satisfactory cutting action.

Brittle materials of the nature of cast iron do not require steep rakes, since they are not removed in the form of continuous chips and are not appreciably work-hardened by cutting operations. Little or no rake is used on brass tools for a similar reason and because of the tendency of brass tools having rake to dig in and chatter.

It is impossible to fix arbitrarily the optimum rake angles for each particular material to be cut, since this most efficient rake angle will vary with the physical condition of the work, the cut, the feed, and the speed as well as other variable quantities. For each class of material there exists, fortunately, not a single value, but a range of angles within which satisfactory results can be obtained. In Table X the rake and clearance angles found through actual practice to yield good results are shown for selected materials.

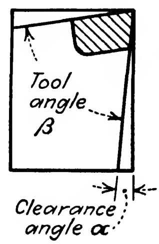
Tool Setting.—Tool setting can be dealt with briefly but nevertheless emphatically. The cutting point should always be on center. Various advantages have been claimed for setting the tool above or below center, but for the great majority of carbide tools, the fact that setting the tool on center permits the use of a proper minimum clearance angle overbalances all others. Setting a tool below center may make possible a still less clearance on outside diameter turning but changes the rake and may cause the tool to dig in.

Recommended tool angles and cutting speeds for different materials are given in Table X.

TABLE X.—RECOMMENDED TOOL ANGLES FOR VARIOUS MATERIALS

These Data Are Based on Turning with Lathe Tools at Approximately ⅛-in. Cut and 1/32-in. Feed per Revolution.

Material cut	Tensile strength 1,000 lb. per sq. in.	Recommended tool angles, deg.			Cutting speed, ft. per min.	Recommended cutting fluid
		Clearance	Side rake	Back rake		
Cast iron 150–170 BHN	18– 26	4	10–12	0– 4	275–350	
Cast iron 1.5 % Ni 170–195 BHN..........	20– 28	4	8–10	0– 4	250–300	
Structural steel 20–30 % steel scrap 2 % Si 170–195 BHN....	30– 36	4	6– 8	0– 2	175–250	
Cast iron 1 % Cr 3.5 % Ni 210 BHN.......	30– 36	4	4– 6	0	150–200	
Malleable cast iron....	....	5	10–12	6	175–250	
S.A.E. 1112 Bess. screw stock..............	70– 90	5– 8	12–20	6–10	300–400	
S.A.E.1120 O. H. screw stock..............	70– 85	5– 8	10–16	5– 8	275–350	
S.A.E. 1020 soft forging	63– 80	4– 6	10–14	5– 7	250–300	Emulsion
S.A.E. 1035..........	75– 90	4– 6	10–12	5– 6	250–300	Emulsion
S.A.E. 1050..........	80–100	4– 6	10–12	5– 6	175–250	Sulphurized mineral oil
S.A.E. 2315 gear blanks	80–115	4– 6	10–12	5– 6	150–200	Emulsion
S.A.E. 3120..........	80–110	4– 6	10–12	5– 6	150–200	Sulphurized mineral oil
S.A.E. 52100.........	100–125	4– 6	10–12	5– 6	150–200	
S.A.E. 6150..........	125–150	4– 6	8–10	4– 5	125–175	Sulphurized mineral oil
18 Cr 8 Ni stainless...	85–110	4– 6	10–14	5– 7	150–200	Sulphurized lard oil
Hi C Hl Cr stainless valve seats.........	100–125	4– 6	8–10	4– 5	100–150	Sulphurized lard oil
Pure cast aluminum No. 43.............	19	8–10	12–16	25–40	500–1000	Kerosene
Dural No. 17 ST......	58	8	0– 3	6	200– 300	Kerosene
Alcoa No. 132—LoEx.	30	6	8–10	14–18	300– 500	Kerosene and lard oil
Rolled copper.........	30	8–12	18–25	4	300– 500	Dry or sweet milk
Cast yellow brass.....	25	6– 8	.....	.....	500– 800	Paraffin oil
Bronze, hard cast S.A.E. No. 62.......	30	6	6–10	0	250– 400	Paraffin oil
Phosphor bronze S.A.E. No. 64.......	25	6	4– 8	0	150– 300	
Glass (drilling)........	....	.....	.....	.....	75– 150	
Unfired clay and porcelain................	....	15–30	.....	10–15	300– 500	
Copper and mica commutators...........	....	8–10	16–20	10–15	300– 500	
Bakelite.............	....	8–10	8–12	4– 6	500– 800	
Casein products.......	....	8–12	4– 6	0– 3	300– 500	
Hard rubber..........	....	8–10	.....	.....	300– 400	



Chilled cast-iron rolls. 10 to 20 ft. per minute. 3-deg. clearance. 0 to 3-deg. back rake. No cutting fluid used.

HOW WESTINGHOUSE USES CARBIDE TOOLS

Tungsten-carbide tools, under several trade names such as Carboloy, Widia, and Firthite, have great possibilities in many lines. As with all new developments, over-enthusiastic advocates used them unwisely and many expensive failures were recorded against them. Being a very hard material, it does not always stand shock well, and vibration in either tool or work is detrimental. The following suggestions by J. M. Highducheck will be found of value in considering their application and in using them in regular work.

Rules Governing the Application of Tungsten-carbide-tipped Tools

Rule 1. Analyze carefully every recommended application before applying tungsten-carbide tools.

Rule 2. Give operator all instructions possible. He appreciates new ideas.

Rule 3. Organize the manufacturing equipment department into a separate division for handling tungsten-carbide-tipped tools. If one division is responsible for purchase, design and application of tools, best results are obtained.

Rule 4. Tungsten carbide is expensive—exercise great care in the selection of tools for each application.

Rule 5. Have a sufficient number of tools for each set-up. All tools require sharpening and the operator should not wait while tools are being resharpened.

Rule 6. Recommend standard tools wherever possible. Inform the operator of the cost of these tools. Keep them sharp and have a suitable place in which to store them when not in use.

Rule 7. Consider tungsten-carbide-tipped tools in the same light as a micrometer and other expensive tools.

Rule 8. Change the tool when it requires regrinding. Do not push it when dull. Teach operators to use honing stones, thus avoiding frequent resharpening of tools.

Rule 9. Tungsten-carbide tools may be ground wet or dry.

Rule 10. Use diamond-lapped edge on cutting tools, especially for finishing operations. This will give the tool a longer life and a finer finish can be had.

Rule 11. Satisfy yourself that the overhang of the tool is not more than one and one-half times the height of the tool and that the largest tool possible of the solid shank type is being used. Demonstrate to the operator the possibilities of this material with each application.

Rule 12. Run the machine at specified feed and speeds, and teach the operator never to stop the machine on a cut. He should always dis-

engage the feed before stopping. Do not use a too heavy feed on castings of frail construction. The work will spring away from the tool and cause a variation in size.

Rule 13. Lathe tools have been designed for specific purposes. Do not use them in boring mills. Ascertain that the machine upon which the application is being made is in good condition.

Rule 14. Obtain the operator's cooperation; united ideas give best results.

Rule 15. Endeavor to make each application a success. Have no more clearance on tools than is absolutely necessary. Have all cutting tools ground on the bottom after hardening. If the bottom is uneven, it is liable to break when clamped in position. Provide supports for all tools as near as possible to the cutting edge. Lack of support sometimes causes unnecessary breakage and chatter. Avoid sharp corners on roughing tools. Feeds and speeds are governed by the depth of cut, the amount of scale, the kind and hardness of material, and the angles of clearance and the top rake on the cutting tool.

Advantages.—The two outstanding advantages of tungsten-carbide tools are the increase in speed with the same cut and feed and the saving in time lost in changing tools, owing to the much longer wear life of the tools. It is advisable to avoid unnecessary difficulties by adopting moderation. In one case it was possible to run a cut at 300 ft. per minute, but it was found advisable to cut the speed to 180 ft. per minute and increase the wear life from 4 hr. to 2 weeks, between grinding the tool. Although TC tools can cut very hard castings that could not otherwise be used, it is not often advisable to accept poor castings on this account.

The introduction of sintered-carbide tools presented new problems to machine-tool builders and users, somewhat as in the case of high-speed steel. Machines had to be made to run at higher speeds and with a minimum of vibration, as this destroyed the cutting edge of the new tools. Tool and work supports had to be heavier. Roller rests on turret lathes had to be stiffer and mounted on better bearings.

The removal of chips, at from three to four times the rate with previous tools, made the problem of chip disposal one of great importance. Continuous chips coming off the work at high speed is a hazard to the workman and must be prevented or controlled. Chip breakers of various kinds have been tried, as has the grinding of the cutting tool so that it curls the chip into a tight helix. In some materials the use of large quantities

of coolant makes the chips brittle enough to break into comparatively small pieces.

Importance of Work Handling Time.—Whenever the machining time of an operation is shortened, the handling time becomes more important. So any increase in cutting speeds makes it necessary to find means of reducing handling time if at all possible. This is evident when cast iron is cut at 210 ft. per minute in some turret lathes, with a cut 0.25 in. deep and feeds of 0.08 to 0.09 in., taking 35 hp. to pull the cut. This means over 26 lb. of metal removed per minute. On cold-finished screw stock such as S.A.E.-X-1315 at 500 ft. per minute and a turning feed of 0.012 in., 35.6 cu. in. of metal, or nearly 10 lb. per minute were removed. Taking care of chips becomes a real problem.

Special training is necessary if these tools are to be used to the best advantage. They must be carefully ground with special grinding wheels, and must be honed for the best results. The smoother the edge and the surface over which the metal must slide, the better results are obtained at these high speeds. Speeds and feeds must be carefully studied for each material and many of our old ideas must be forgotten. Generally speaking, we must use light cuts, light feeds, and high speeds for best results. When cemented-carbide tools are to be introduced in a shop, we advise that one man be first thoroughly trained in their use and then devote all his time to the proper training of others until all become thoroughly familiar with the new problems involved in the use of these new tools.

Carbide Tooling on Present Equipment.—While tools of tungsten or tantalum carbide show their best qualities where the machines on which they are used can be run at very high speeds, they can also show distinct savings where the only advantage is the greatly increased length of tool life between grinds. Rigidity of the machine should also be considered on medium and heavy work, as vibration is destructive to carbide tools. But for light work, such as brass castings in plumbing or similar supplies, and in hand turret work, almost any serviceable machine can be made to show a substantial increase in production with carbide tools.

William Calkins, production engineer of the Geo. D. Roper Corporation, Rockford, Ill., uses carbide-tipped tools in the

box tools used on small turret lathes. The chief gain was in saving time from combined operations and continuous production. The hourly rate was not increased but a 15-min. delay every 2 hr. in changing high-speed tools was avoided. On one job where 200 pieces was the limit between grinds, they now finish 15,000 before the tools need attention.

On one milling job, on brass, a cutting speed of 250 ft. per minute is used with a feed of 23 in. per minute. A 30-in. feed could be used, but the machine will not stand it. This doubled the output over the old method. And they get 1,750 pieces per grind as against 200 for the old cutters.

Sizes of Tungsten-carbide Tips.—Much of the success of tools with tungsten-carbide cutting tips depends on selecting the proper size and kind of shank, and using a tip large enough to stand the cutting pressure without danger of breaking. On the other hand, the cost of tungsten-carbide tips makes it imperative for users not to order them larger than necessary.

Then, too, experience has shown that shanks, or holders, must be of sufficient size to support the tips rigidly. Instead of low-carbon steel, makers of tungsten-carbide tips advise that shanks be made of high-carbon tool steel both because of its stiffness and because it brazes very satisfactorily. The brazing temperature, however, produces a growth of grain size, and in work requiring heavy tool pressure special steels are recommended for tool shanks. One company uses S.A.E. steel No. 2340 for shanks with good results.

While many tungsten-carbide tips are made for tool-holder bits, makers prefer to have them used on solid shanks, as these shanks provide better support for the cutting edge. The tool bit necessarily extends from its holder and this overhang permits more vibration than where the support runs down to the tool post or tool block itself.

Makers of tungsten-carbide tips have standardized the sizes to a considerable extent. While these sizes are not universal to the extent that all tips of different makers are the same size, they are not far apart in general dimensions. The smallest regular tip for turning tool bits is $3/32$ in. thick, $5/32$ in. wide, and $3/8$ in. long, while for solid turning tools the thickness is the same but the width is $5/16$ in. The length varies with different makers, $7/8$ in. being the minimum for solid bits in one case.

The thickness varies with the work to be done. And even the makers are not agreed as to the best thickness in all cases.

TOOL GRINDING

Uniform tool grinding is considered essential to both accuracy and economy in manufacture. Some advocate the centralization of all tool grinding in one department while others find it best to have the tool grinding done in the tool crib of each department. This applies principally to the smaller tools. As a rule, all large and universally used tools, or those which require several successive operations to give the proper cutting edge, are ground in a central department. Special grinding rooms are also frequently provided for such tools as are used in gear cutting, whether for plain or spiral bevels or for hobbed gears, or for worm gearing.

Tool-crib attendants can frequently find time to sharpen taps and drills, tool bits, and other tools. They salvage high-speed drills by cutting off the carbon shank with a flexible grinding wheel in order to get a higher price for the scrap steel, and do other work of a similar character. They inspect gages periodically.

The proper grinding of sintered-carbide tools, however, requires care. The importance of keeping these tools in first-class condition demands the best of grinding equipment especially adapted for this work. Detailed directions, prepared by the Carborundum Company, follow:

Side Grinding:

1. Set table to correct angle (Fig. 21).
2. Rough grind side clearance (Fig. 22).
3. Adjust table and rough grind top rake (Fig. 23).
4. Adjust table and rough grind front clearance (Fig. 24).
5. Adjust table and finish grind side clearance.
6. Adjust table and finish grind top rake.
7. Adjust table and finish grind front clearance.
8. Finish grind radius on nose (Fig. 25).

Note: The above procedure is for a right-hand tool. The order for a left-hand tool is, top, side, front. The order is merely so that the operator can better watch the grinding. Some may prefer to grind the front first, the side next, and the top last.

Rough Grind on Periphery—Finish Grind on Side:

1. Set table to correct angle (Fig. 26).
2. Rough grind side clearance (Fig. 27).

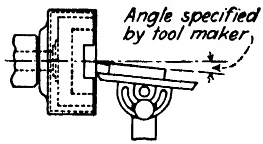


FIG. 21.

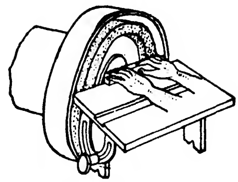


FIG. 22.

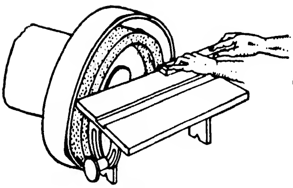


FIG. 23.

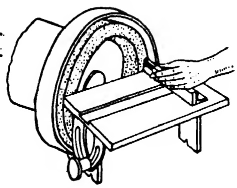


FIG. 24.

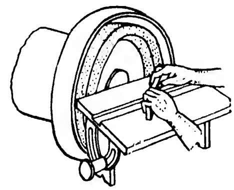


FIG. 25.

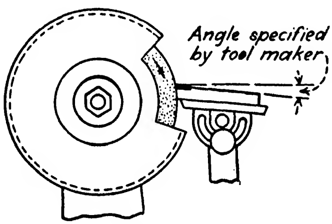


FIG. 26.

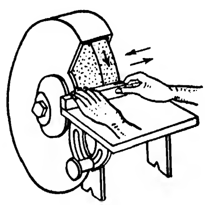


FIG. 27.

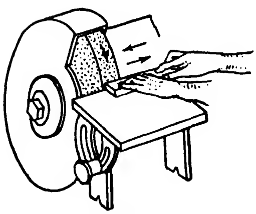


FIG. 28.

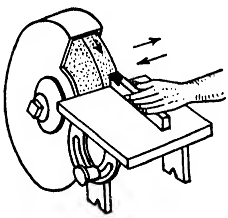
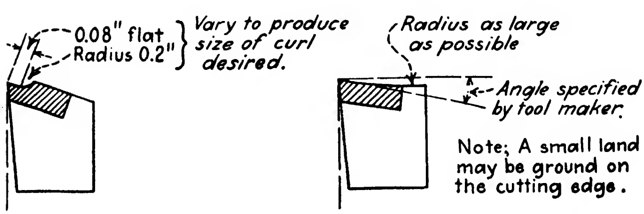


FIG. 29.



a *b*

FIG. 30.—(*a*) Grinding chip breaker on the periphery of a wheel; (*b*) an alternate method of grinding chip breaker.

3. Adjust table and rough grind top rake (Fig. 28).
4. Adjust table and rough grind front clearance (Fig. 29).

Grinding Chip Breakers.—Special wheels are required for grinding sintered-carbide tools. Side grinding on cup or ring wheels avoids hollow grinding the clearance angles. Rough grinding on the periphery of a plain wheel and finish grinding on the side (see set-ups in Figs. 21 to 24 under side grinding) is faster than side grinding for both operations. Care should be taken to remove all the undercut on the tip, although some undercut may be left on the shank.

Chip breakers may be ground free-hand on the periphery of a grinding wheel. The back rake, or top side rake if one is ground, must not be too great or weakening of the cutting edge will result. A slight land at the cutting edge may be necessary on some tools for some operations. (See Fig. 30.)

Machine Grinding on Tool Grinders.

1. Set-up tool in holder so that correct angles will be maintained (Fig. 31).
2. Bring tool to the wheel and grind nose by passing the tool up and down across wheel face, feeding wheel in slowly, and feeding the tool across the wheel face horizontally (Fig. 32).
3. Repeat 1, 2 for sides and top (Fig. 33).
4. Where radius (¼ in. and over) on nose must be ground, or where radius must be exactly smooth, use special forming attachment with suitable cam to develop correct shape (Fig. 34).
5. For small radii (under ¼ in.) grind 1 flat at 45 deg. and 2 small flats at 22½ deg. and 67½ deg. by means of suitable adjustments of the tool holder (Fig. 35).

Machine Lapping.

1. Adjust table to correct angle and place a small quantity of diamond dust and olive oil on the tool while it is in position against the rotating disk (Fig. 36).
2. Lap nose by holding tool against disk, moving it across the disk (Fig. 37).
3. Lap both sides as above (Fig. 38).
4. Lap top as above (Fig. 39).

One type of tool grinder uses a plain wheel, as shown, and grinds on the periphery of the wheel. The plain wheel has the advantage that grinding is done by line contact, but will give a straight line from the heel to toe of the tool. The other machine employs a cup wheel, which has the advantage of constant peripheral speed of the wheel. General instructions are as follows: (1) Use light feeds; (2) be sure that the work is flooded with water; (3) large radii may be ground by the use of a special cam in the tool holder; and (4) in grinding curved-face tools have the cutting edge as close as possible to the cam.

Tools used for fine finishing cuts and those used on materials having a highly abrasive action should be lapped. By the use of the newly developed diamond wheel in the fine or extra-fine grits, the necessity for lapping is eliminated. Lapping can be done with two materials, diamond dust or silicon carbide finishing compound. Machines for the lapping of cemented-carbide tools usually have a horizontal or a vertical disk directly connected

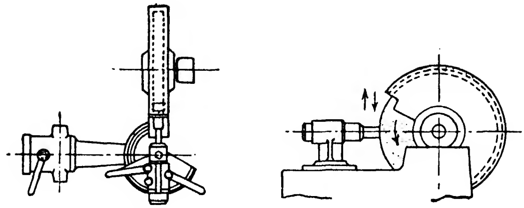


Fig. 31.

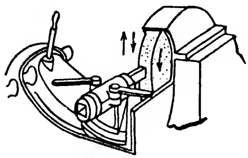


Fig. 32.

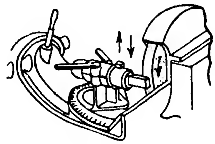


Fig. 33.

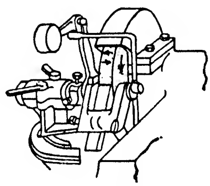


Fig. 34.

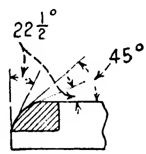


Fig. 35.

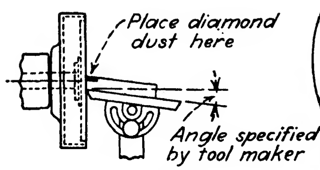


Fig. 36.

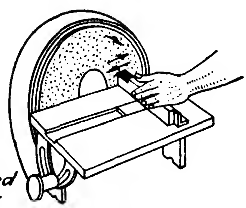


Fig. 37.

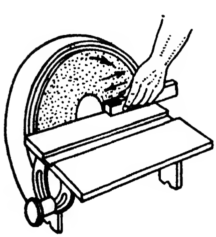


Fig. 38.

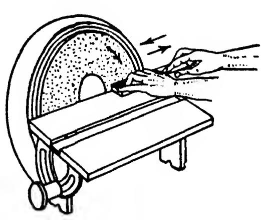


Fig. 39.

to a motor and running at quite a high speed. The machines intended for the use of silicon carbide compound should be speeded lower, 900 to 1,200 surface ft. per minute being recommended. Higher speeds cause the compound to fly off the disk, resulting in slow cutting. In many cases the disk speed for diamond lapping is also too high for efficient operation.

Set the table of the lapping machine ½ deg. less than the angle used for the grind. This will develop the cutting edge and make operation much faster than lapping the entire surface of the tool. General instructions are as follows: (1) Use diamond dust sparingly because the disk is impregnated and diamond dust is expensive; (2) work should be examined frequently under at least a 10-power magnifying glass to determine the keenness of the cutting edge; (3) the direction of rotation of the disk should be against the cutting edge of the tool; (4) lapping should be continued until all grinding marks are out.

The method of lapping with compound is the same as with diamond dust except that: (1) Enough compound should be used to form a film between the tool and the disk; (2) it is not necessary to impregnate the disk with abrasive.

The Heald Machine Company makes a special machine for grinding tools for boring heads, and the Ex-Cell-O aircraft and Tool Co. build a machine designed for using the new diamond grinding wheels.

Carbide and Diamond Boring.—Cast-iron pistons for refrigerator units have pinholes 0.4995 to 0.4997 by 1⅛₂ in. long. These are bored with carbide-tipped tools at 2,000 r.p.m. with a feed of 0.005 in. per revolution. A similar hole in the bronze connecting rod is bored 2,400 r.p.m. with a feed of 0.001 in. per revolution. The large end is 1.1877 to 1.1882 by ⅞ in. at 1500 r.p.m. and a feed of 0.001 in. per revolution.

A cast-iron cylinder 1.312 to 1.316 by 1¾ in. is bored at 900 r.p.m. and a feed of 0.005 in. per revolution.

Bronze bushings 1 by 2$\frac{9}{16}$ in. are bored with diamond tools at 3,600 r.p.m. and a feed of 0.0015 in. per revolution. The tolerance is minus 0.0005 in. Bronze seal rings are turned and faced with diamond tools with accuracy equaling former facing and lapping.

Tool Holder for Carbide-tipped Turning Tools.—Experience at the Watertown Arsenal in turning shells during the war developed the advisability of using a tool holder for carbide-tipped tools. The tool furnished by the maker of the shell-turning lathe had a shank 1¾ by 2¼ in. which weighed 14 lb. This was difficult to handle in grinding the carbide tip, and the

large steel faces of the tool promoted heat cracks in the tip itself. In addition it was difficult to find steel of that size for shanks.

FIG. 40.—Holder for carbide-tipped lathe tool.

To overcome this W. B. Kennedy, tool engineer of the shops, designed the tool holder shown in Fig. 40 which enabled the tool grinder to handle over four times as many tools per day, owing

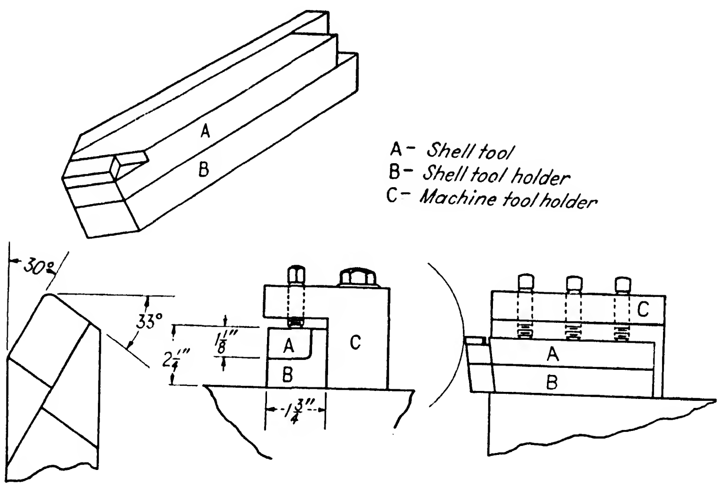


FIG. 41.—How tool holder was clamped in lathe.

to the decrease in size and weight. The time for brazing the tip and other handling was also cut in half. The shank that held the carbide tip was $1\frac{1}{8}$ in. deep, as shown, and was supported by a substantial holder $1\frac{3}{4}$ in. square. The assembly and the way

in which the tool was held in the lathe are also shown in Fig. 41.

The angles of the roughing tool were as follows:

End-cutting edge angle	33 deg.
Side-cutting edge angle	30 deg.
Nose radius	3/64 in.
End clearance	7 deg.
Side clearance	7 deg.
Back rake	0
Side rake	6 deg.

The finishing tool had a nose radius of 5/64 in., this being the only difference between the two tools. The end cutting was determined by the tool feeding into the shell at 25 deg., which left an 8-deg. clearance angle. The nose radius of the finishing tool gave a surface of 450 microinches, or less.

CUTTING STEEL WITH CARBIDE TOOLS

In the early days of Carboloy and other sintered-carbide tools, the tools were not recommended for cutting steel. In most cases they were suggested for use on cast ferrous metals and nonferrous materials. Improvements have been made in all carbide tools that now make them available for use on steel. Carboloy Company, Inc., suggests that the operator be sure that there is sufficient power at the machine to pull the cut, as stalling causes tool failure. The company also suggests the following formula for power required:

$$\text{Hp} = D \times F \times S \times C$$

where D = depth of cut in inches.
F = feed in inches per revolution.
S = surface feet per minute.
C = power constant—from the following tables.

Tool Angles.*—Tool angles in the tables that follow are *measured with the work.* Bold-face type indicates the angles one should start with, and the angles shown in light-face type indicate the range of practical angles. Bold-face type also suggests starting speed.

* Courtesy of Carboloy Company, Inc.

TABLE XI.—CUTTING STEEL—AVERAGE WORK

Steel		Power constant*	Cut ¼ to ½ f.p.m.	Feed 1/32 max. Grade	Cut ⅛ to 7/32 f.p.m.	Feed 1/32 max. Grade	Cut 3/64 to 3/32 f.p.m.	Feed 0.020 max. Grade	Cut 1/64 to 1/32 f.p.m.	Feed 0.010 max. Grade	Front relief	Side relief	Back rake	Side rake
Carbon	S.A.E. 1010–1025	6	150–350 **300**	**78B**	200–600 **400**	**78B** 78	300–800 **600**	**78** 831	500–1800 **600**	**78** 831	6–12 **7**	6–12 **7**	0–15 **0**	8–15 **8**
	S.A.E. 1030–1095	8	150–350 **275**	**78B**	150–350 **275**	**78B** 78	200–350 **275**	**78B** 78	300–600 **400**	**78B** 78	5–10 **7**	5–10 **7**	0–10 **0**	4–12 **8**
Free cutting	S.A.E. 1112–1120	6	150–350 **300**	**78B**	200–600 **400**	**78B** 78	300–800 **600**	**78** 831	500–1800 **600**	**78** 831	6–12 **7**	6–12 **7**	0–15 **0**	8–15 **8**
	S.A.E. X1314–X1340	6	150–350 **275**	**78B**	150–350 **275**	**78B** 78	200–350 **275**	**78** 831	250–500 **350**	**78** 831	6–12 **7**	6–12 **7**	0–10 **0**	4–12 **8**
Mn.	S.A.E. T1330–T1350	9	150–350 **275**	**78B**	150–350 **275**	**78B** 78	200–350 **275**	**78B** 78	250–500 **350**	**78B** 78	5–10 **7**	5–10 **7**	0–10 **0**	4–12 **8**
Nickel	S.A.E. 2015–2320	7	150–350 **300**	**78B**	150–350 **300**	**78B** 78	250–500 **300**	**78** 831	400–600 **500**	**78** 831	6–12 **7**	6–12 **7**	0–15 **0**	8–15 **8**
	S.A.E. 2330–2350	9	150–350 **275**	**78B**	150–350 **275**	**78B** 78	200–350 **275**	**78B** 78	250–500 **350**	**78B** 78	5–10 **7**	5–10 **7**	0–10 **0**	4–12 **8**
Nickel-chrome	S.A.E. 3115–3130	8	150–350 **300**	**78B**	150–350 **300**	**78B** 78	250–500 **300**	**78** 831	250–500 **350**	**78** 831	6–12 **7**	6–12 **7**	0–15 **0**	8–15 **8**
	S.A.E. 3135–3450	9	150–350 **275**	**78B**	150–350 **275**	**78B** 78	200–350 **275**	**78B** 78	250–500 **350**	**78B** 78	5–10 **7**	5–10 **7**	0–10 **0**	4–12 **8**
Mo.	S.A.E. 4130–4820	9	150–300 **250**	**78B**	150–300 **250**	**78B** 78	200–350 **275**	**78B** 78	250–500 **350**	**78B** 78	5–10 **7**	5–10 **7**	0–10 **0**	4–12 **8**
Cr.	S.A.E. 5120–52100	10	150–300 **250**	**78B**	150–300 **250**	**78B** 78	200–350 **250**	**78B** 78	250–500 **350**	**78B** 78	5–10 **7**	5–10 **7**	0–10 **0**	4–12 **8**
Cr. V.	S.A.E. 6115–6195	10	150–300 **250**	**78B**	150–300 **250**	**78B** 78	200–350 **250**	**78B** 78	250–500 **350**	**78B** 78	5–10 **7**	5–10 **7**	0–10 **0**	4–12 **8**
	Cast steel	9	150–300 **250**	**78B**	150–350 **275**	**78B** 78	150–350 **275**	**78B** 78	150–350 **300**	**78B** 78	5–10 **7**	5–10 **7**	0–10 **0**	4–12 **8**

* For calculation of power required, using power constant, and for multiple-diameter work, see page 429.

TABLE XII.—CUTTING STEEL—LARGE WORK ON HEAVY BORING MILLS, LATHES, ETC., WHERE HIGH CUTTING SPEEDS ARE NOT PRACTICAL

IMPORTANT.—For steel over 400 Brinell, check power at machine.		Power constant*	Cut 9/16 to 3/4	Feed 3/32 max.	Cut 3/8 to 1/2	Feed 1/16 max.	Cut 3/16 to 5/16	Feed 3/64 max.	Front relief	Side relief	Back rake	Side rake
			f.p.m.	Grade	f.p.m.	Grade	f.p.m.	Grade				
Carbon	S.A.E. 1010–1025	6	80–125 **100**	**55A** 78A	125–175 **150**	**55A** 78A	150–250 **200**	**55A** 78A	6–10 **6**	6–10 **6**	0–6 Neg. **0**	6–10 **6**
	S.A.E. 1030–1095	8	60–100 **80**	**55A** 78A	100–150 **120**	**55A** 78A	125–200 **150**	**55A** 78A	5–10 **6**	5–10 **6**	0–6 Neg. **0**	6–10 **6**
Free cutting	S.A.E. 1112–1120	6	80–125 **100**	**55A** 78A	125–175 **150**	**55A** 78A	150–250 **200**	**55A** 78A	6–10 **6**	6–10 **6**	0–6 Neg. **0**	6–10 **6**
	S.A.E. X1314–X1340	6	60–100 **80**	**55A** 78A	100–150 **120**	**55A** 78A	125–200 **150**	**55A** 78A	6–10 **6**	6–10 **6**	0–6 Neg. **0**	6–10 **6**
Mn.	S.A.E. T1330–T1350	9	60–100 **80**	**55A** 78A	100–150 **120**	**55A** 78A	125–200 **150**	**55A** 78A	5–10 **6**	5–10 **6**	0–6 Neg. **0**	6–10 **6**
Nickel	S.A.E. 2015–2320	7	80–125 **100**	**55A** 78A	125–175 **150**	55A 78A	150–250 **200**	**55A** 78A	6–10 **6**	6–10 **6**	0–6 Neg. **0**	6–10 **6**
	S.A.E. 2330–2350	9	60–100 **80**	**55A** 78A	100–150 **120**	**55A** 78A	125–200 **150**	**55A** 78A	5–10 **6**	5–10 **6**	0–6 Neg. **0**	6–10 **6**
Nickel-chrome	S.A.E. 3115–3130	8	60–100 **80**	**55A** 78A	100–150 **120**	**55A** 78A	125–200 **150**	**55A** 78A	6–10 **6**	6–10 **6**	0–6 Neg. **0**	6–10 **6**
	S.A.E. 3135–3450	9	60–180 **80**	**55A** 78A	100–150 **120**	**55A** 78A	125–200 **150**	**55A** 78A	5–10 **6**	5–10 **6**	0–6 Neg. **0**	6–10 **6**
Mo.	S.A.E. 4130–4820	9	60–100 **80**	**55A** 78A	100–150 **120**	**55A** 78A	125–200 **150**	**55A** 78A	5–10 **6**	5–10 **6**	0–6 Neg. **0**	6–10 **6**
Cr.	S.A.E. 5120–52100	10	60–100 **80**	**55A** 78A	100–150 **120**	**55A** 78A	125–200 **150**	**55A** 78A	5–10 **6**	5–10 **6**	0–6 Neg. **0**	6–10 **6**
Cr. V.	S.A.E. 6115–6195	10	60–100 **80**	**55A** 78A	100–150 **120**	**55A** 78A	125–200 **150**	**55A** 78A	5–10 **6**	5–10 **6**	0–6 Neg. **0**	6–10 **6**
	Cast steel	9	60–100 **80**	**55A** 78A	100–150 **120**	**55A** 78A	125–200 **150**	**55A** 78A	5–10 **6**	5–10 **6**	0–6 Neg. **0**	6–10 **6**

* For calculation of power required, using power constant, and for multiple-diameter work, see page 429.

TABLE XIII.—MACHINING FERROUS CASTINGS AND NONFERROUS MATERIALS—AVERAGE WORK

Metal		Power constant*	Cut ¼ to ½ f.p.m.	Feed 1/32 max. Grade	Cut ⅛ to 7/32 f.p.m.	Feed 1/32 max. Grade	Cut 3/64 to 3/32 f.p.m.	Feed 0.020 max. Grade	Cut 1/64 to 1/32 f.p.m.	Feed 0.010 max. Grade	Front relief	Side relief	Back rake	Side rake
Cast iron	Hard (no alloy)	4	150–250 **200**	**44A** 883	150–250 **200**	**883** 905	150–350 **250**	**883** 905	150–350 **250**	**883** 905	4–6 **5**	4–6 **5**	0–6 **0**	0–10 **5**
	Medium (no alloy)	3	200–300 **250**	**44A** 883	200–300 **250**	**883** 905	200–350 **250**	**883** 905	200–350 **250**	**883** 905	4–8 **7**	4–8 **7**	0–6 **0**	0–10 **8**
	Soft (no alloy)	3	200–350 **250**	**44A** 883	200–350 **250**	**883** 905	200–350 **250**	**883** 905	250–450 **300**	**883** 905	4–10 **7**	4–10 **7**	0–6 **0**	0–12 **8**
	Hard (alloy)	4	150–250 **200**	**44A** 883	150–250 **200**	**883** 907	150–350 **250**	**883** 905	150–350 **250**	**883** 905	4–6 **5**	4–6 **5**	0–6 **0**	0–8 **5**
	Medium (alloy)	3	150–250 **200**	**44A** 883	150–250 **200**	**883** 907	150–350 **250**	**883** 905	150–350 **250**	**883** 905	4–8 **7**	4–8 **7**	0–6 **0**	0–10 **8**
	Soft (alloy)	3	200–350 **250**	**44A** 883	200–350 **250**	**883** 907	200–350 **250**	**883** 905	250–450 **300**	**883** 905	4–10 **7**	4–10 **7**	0–6 **0**	0–10 **8**
	Up to 25% semisteel	3	150–350 **250**	**44A** 883	150–350 **250**	**883** 907	150–350 **250**	**883** 905	150–350 **250**	**883** 905	5–8 **7**	5–8 **7**	0–6 **0**	5–10 **8**
	Over 25% semisteel	4	100–250 **200**	**44A** 883	100–250 **200**	**883** 907	150–350 **250**	**883** 905	150–350 **250**	**883** 905	4–8 **7**	4–8 **7**	0–6 **0**	5–10 **8**
	Brake drums heat-treated	4	150–350 **250**	**44A** 883	150–350 **250**	**883** 907	200–350 **300**	**883** 905	250–450 **350**	**883** 905	4–8 **7**	4–8 **7**	0–6 **0**	0–10 **8**
	Brake drums centrifugal	4	150–350 **250**	**44A** 883	150–350 **250**	**883** 907	150–350 **250**	**883** 905	250–450 **350**	**883** 905	4–8 **7**	4–8 **7**	0–6 **0**	0–10 **8**
	Chilled rolls	5	10–45 **15**	**44A** 883	10–45 **15**	**44A** 883	10–45 **15**	**44A** 883	10–45 **15**	**883** 905	3–5 **3**	3–5 **3**	0–0 **0**	0–5 **0**
Malleable iron	Hard	5	100–200 **150**	**44A** 883	100–200 **150**	**883** 907	150–250 **200**	**883** 907	150–350 **250**	**883** 907	4–6 **5**	4–6 **5**	0–6 **0**	0–8 **5**
	Medium	4	150–250 **200**	**44A** 883	150–250 **200**	**883** 907	150–350 **250**	**883** 907	150–350 **250**	**883** 907	4–8 **7**	4–8 **7**	0–6 **0**	0–10 **8**
	Soft	3	200–350 **250**	**44A** 883	200–350 **250**	**883** 907	200–350 **250**	**883** 907	250–450 **300**	**883** 907	4–8 **7**	4–8 **7**	0–6 **0**	0–12 **8**

* For calculation of power required, using power constant, and for multiple-diameter work, see page 429.

TABLE XIV.—MACHINING FERROUS CASTINGS AND NONFERROUS MATERIALS—LARGE WORK ON HEAVY BORING MILLS, LATHES, ETC., WHERE HIGH CUTTING SPEEDS ARE NOT PRACTICAL

Metal		Power constant*	Cut 9/16 to 3/4 f.p.m.	Feed 3/32 max. Grade	Cut 3/8 to 1/2 f.p.m.	Feed 1/16 max. Grade	Cut 3/16 to 5/16 f.p.m.	Feed 3/64 max. Grade	Cut 1/8 to 1/4 f.p.m.	Feed 1/32 max. Grade	Front relief	Side relief	Back rake	Side rake
Cast iron	Hard (no alloy)	4	60–125 **80**	**55A** 44A	60–125 **80**	**55A** 44A	60–125 **80**	**55A** 44A	60–150 **100**	**55A** 44A	4–6 **4**	4–6 **4**	0–6 **0**	0–8 **6**
	Medium (no alloy)	3	60–200 **125**	**55A** 44A	60–200 **125**	**55A** 44A	60–200 **125**	**55A** 44A	60–250 **150**	**55A** 44A	4–6 **4**	4–6 **4**	0–6 **0**	0–8 **6**
	Soft (no alloy)	3	80–250 **150**	**55A** 44A	80–250 **150**	**55A** 44A	80–250 **150**	**55A** 44A	80–250 **200**	**55A** 44A	4–6 **6**	4–6 **6**	0–6 **0**	6–12 **8**
	Hard (alloy)	4	60–125 **80**	**55A** 44A	60–125 **80**	**55A** 44A	60–125 **80**	**55A** 44A	60–150 **100**	**55A** 44A	4–6 **4**	4–6 **4**	0–6 **0**	0–6 **4**
	Medium (alloy)	3	60–150 **100**	**55A** 44A	60–150 **100**	**55A** 44A	60–150 **100**	**55A** 44A	60–200 **125**	**55A** 44A	4–6 **4**	4–6 **4**	0–6 **0**	0–8 **6**
	Soft (alloy)	3	80–250 **150**	**55A** 44A	80–250 **150**	**55A** 44A	80–250 **150**	**55A** 44A	80–250 **200**	**55A** 44A	4–8 **6**	4–8 **6**	0–6 **0**	6–12 **8**
	Up to 25% semisteel	3	80–250 **150**	**55A** 44A	80–250 **150**	**55A** 44A	80–250 **150**	**55A** 44A	80–250 **150**	**55A** 44A	4–8 **6**	4–8 **6**	0–6 **0**	6–12 **8**
	Over 25% semisteel	4	60–200 **100**	**55A** 44A	60–200 **100**	**55A** 44A	60–200 **100**	**55A** 44A	80–250 **150**	**55A** 44A	4–8 **6**	4–8 **6**	0–6 **0**	4–10 **8**
	Brake drums heat-treated	4	......	...	......	...	......	...	150–350 **200**	**44A** 907	4–8 **6**	5–8 **6**	0–6 **5**	0–10 **8**
	Brake drums centrifugal	4	......	...	......	...	......	...	150–350 **200**	**44A** 907	4–8 **6**	4–8 **6**	0–6 **5**	0–10 **8**
	Chilled rolls	5	......	...	......	...	10–45 **15**	**44A** 883	10–45 **15**	**44A** 883	3–5 **3**	3–5 **3**	0–0 **0**	0–5 **0**
Malleable iron	Hard	5	60–125 **80**	**55A** 44A	60–125 **80**	**55A** 44A	60–125 **80**	**55A** 44A	60–150 **100**	**44A** 883	4–6 **5**	4–6 **5**	0–6 **5**	0–8 **5**
	Medium	4	60–150 **100**	**55A** 44A	60–150 **100**	**55A** 44A	60–150 **100**	**55A** 44A	60–200 **125**	**44A** 883	4–6 **5**	4–6 **5**	0–6 **5**	0–10 **8**
	Soft	3	60–250 **150**	**55A** 44A	60–250 **150**	**55A** 44A	60–250 **150**	**55A** 44A	80–250 **200**	**44A** 883	4–8 **6**	4–8 **6**	0–6 **5**	0–12 **8**

* For calculation of power required, using powor constant, and for multiple-diameter work, see page 429.

Table XV.—Machining Nonferrous and Nonmetallic Materials—Average Work

Material		Power constant*	Cut ¼ to ½ f.p.m.	Feed 1/32 max. Grade	Cut ⅛ to 7/32 f.p.m.	Feed 1/32 max. Grade	Cut 3/64 to 3/32 f.p.m.	Feed 0.020 max. Grade	Cut 1/64 to 1/32 f.p.m.	Feed 0.010 max. Grade	Front relief	Side relief	Back rake	Side rake
Bronze	Hard	10	100–300 **200**	**44A** 883	150–350 **250**	**44A** 883	200–400 **300**	**883** 905	200–600 **400**	**883** 905	4–6 **5**	4–6 **5**	0–5 **0**	4–8 **4**
	Soft	4	150–400 **300**	**44A** 883	200–500 **350**	**883** 905	250–600 **400**	**883** 905	300–1000 **500**	**883** 905	6–8 **7**	6–8 **7**	0–10 **0**	4–10 **8**
Brass	Hard	10	100–300 **200**	**55A** 44A	150–350 **250**	**44A** 883	200–400 **300**	**883** 905	200–600 **400**	**883** 905	4–6 **5**	4–6 **5**	0–5 **0**	4–8 **4**
	Soft	4	150–400 **300**	**44A** 883	200–500 **350**	**883** 905	250–600 **400**	**883** 905	300–1000 **500**	**883** 905	6–8 **7**	6–8 **7**	0–10 **0**	4–10 **8**
Aluminum	Castings	3	150–500 **300**	**44A** 883	200–700 **350**	**883** 905	250–1000 **400**	**883** 905	300–1500 **500**	**883** 905	6–10 **7**	6–10 **7**	5–15 **10**	8–15 **8**
	Bar stock	4	150–500 **300**	**44A** 883	200–700 **350**	**883** 905	250–1000 **400**	**883** 905	300–1500 **500**	**883** 905	6–10 **7**	6–10 **7**	5–15 **10**	8–15 **8**
Zinc alloy	Die castings	3	....	...	200–500 **350**	**883** 905	250–600 **400**	**883** 905	300–1000 **500**	**905** 999	6–10 **7**	6–10 **7**	5–15 **10**	8–15 **8**
Rubber	Hard	..	....	...	250–400 **350**	**883** 905	250–600 **400**	**883** 905	300–800 **500**	**905** 999	6–10 **7**	6–10 **7**	15–35 **20**	8–25 **10**
	Soft	..	....	...	300–600 **450**	**883** 905	400–800 **600**	**883** 905	600–1000 **800**	**883** 905	8–15 **10**	8–15 **10**	15–35 **25**	8–25 **20**
	Copper	4	100–300 **200**	**44A** 883	200–500 **350**	**44A** 883	250–600 **400**	**883** 905	300–1000 **500**	**883** 905	7–10 **7**	7–10 **7**	6–10 **8**	15–25 **15**
	Commutators	4	....	...	100–400 **150**	**55A** 44A	100–600 **200**	**44A** 883	150–1000 **300**	**44A** 883	3–8 **7**	3–8 **7**	0–10 **8**	8–20 **15**
	Fiber	..	200–350 **300**	**44A** 883	250–500 **400**	**44A** 883	250–600 **500**	**883** 905	300–800 **600**	**883** 905	6–10 **7**	6–10 **7**	0–10 **5**	8–15 **10**
	Plastics	..	....	...	250–800 **400**	**44A** 883	300–1000 **600**	**883** 905	500–1500 **800**	**883** 905	6–10 **7**	6–10 **7**	0–10 **5**	8–15 **10**

* For calculation of power required, using power constant, and for multiple-diameter work, see page 429.

TABLE XVI.—MACHINING NONFERROUS AND NONMETALLIC MATERIALS—LARGE WORK ON HEAVY BORING MILLS, LATHES, ETC., WHERE HIGH CUTTING SPEEDS ARE NOT PRACTICAL

Materials		Power constant*	Cut	Feed	Cut	Feed	Cut	Feed	Cut	Feed	Front relief	Side relief	Back rake	Side rake
			½ to ¾	3/32 max.	⅜ to ½	1/16 max.	¼ to ⅜	3/64 max.	⅛ to ¼	1/32 max.				
			f.p.m.	Grade	f.p.m.	Grade	f.p.m.	Grade	f.p.m.	Grade				
Brass	Hard	10	60–100 **80**	**55A** 44A	60–150 **100**	**55A** 44A	60–200 **125**	**55A** 44A	60–250 **150**	**44A** 883	4–6 **5**	4–6 **5**	0–5 **0**	4–8 **4**
	Soft	4	100–400 **150**	**55A** 44A	100–400 **200**	**55A** 44A	100–400 **200**	**55A** 44A	100–500 **250**	**44A** 883	6–8 **6**	6–8 **6**	0–10 **0**	4–10 **6**
Bronze	Hard	10	60–100 **80**	**55A** 44A	60–150 **100**	**55A** 44A	60–200 **125**	**55A** 44A	60–250 **150**	**55A** 44A	4–6 **5**	4–6 **5**	0–5 **0**	4–8 **4**
	Soft	4	100–400 **150**	**55A** 44A	100–400 **200**	**55A** 44A	100–400 **200**	**55A** 44A	100–500 **250**	**44A** 883	6–8 **6**	6–8 **6**	0–10 **0**	4–10 **6**
Aluminum	Castings	3	80–400 **100**	**55A** 44A	80–400 **150**	**55A** 44A	100–400 **200**	**55A** 44A	100–500 **300**	**44A** 883	6–10 **7**	6–10 **7**	5–15 **10**	8–15 **8**
	Bar stock	4	80–400 **100**	**55A** 44A	80–400 **150**	**55A** 44A	100–200 **150**	**55A** 44A	100–500 **300**	**44A** 883	6–10 **7**	6–10 **7**	5–15 **10**	8–15 **8**
	Copper	4	80–150 **100**	**55A** 44A	80–150 **125**	**55A** 44A	100–200 **150**	**55A** 44A	100–250 **200**	**44A** 883	7–10 **7**	7–10 **7**	5–10 **8**	8–15 **15**

* For calculation of power required, using power constant, and for multiple-diameter work, see page 429.

CARBIDE TOOLS ON STEEL FORGINGS

Important applications of carbide cutting tools in the production of equipment and machinery parts are to be found in up-to-date and progressive plants throughout most manufacturing areas in the United States. This applies to the machining of heavy and medium castings, forgings, and bar material, as well as of the lighter classes of products commonly manufactured in

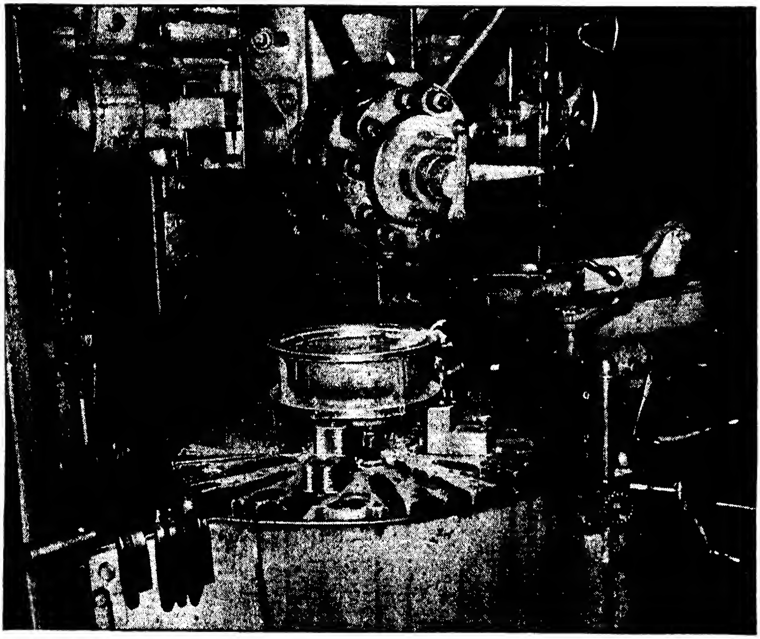


FIG. 42.—Boring and facing stainless-steel pump part.

great volume in the numerous shops and plants devoted largely to producing aircraft accessories and allied lines of metalwork.

A Southern California plant making extensive use of Carboloy tools produces as a regular line of manufacture high-pressure, hot-oil centrifugal pumps, streamlined oil-well pumps, etc. Various operations accomplished rapidly and economically at the Pacific Pump Works with the type of cutting tools mentioned above are represented here.

Boring, facing, and turning operations in a 42-in. Bullard vertical turret lathe are represented in Fig. 42. The job is a

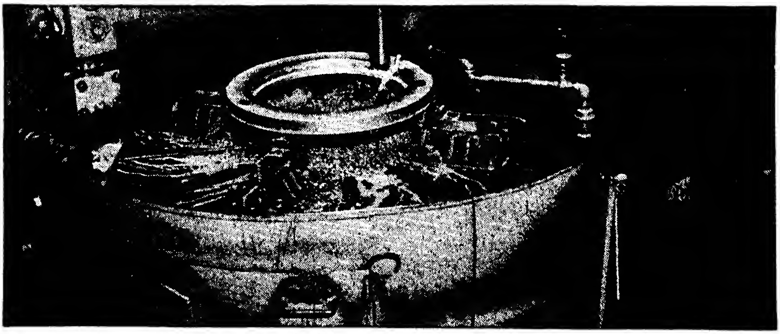


FIG. 43.—Another part of a pump job.

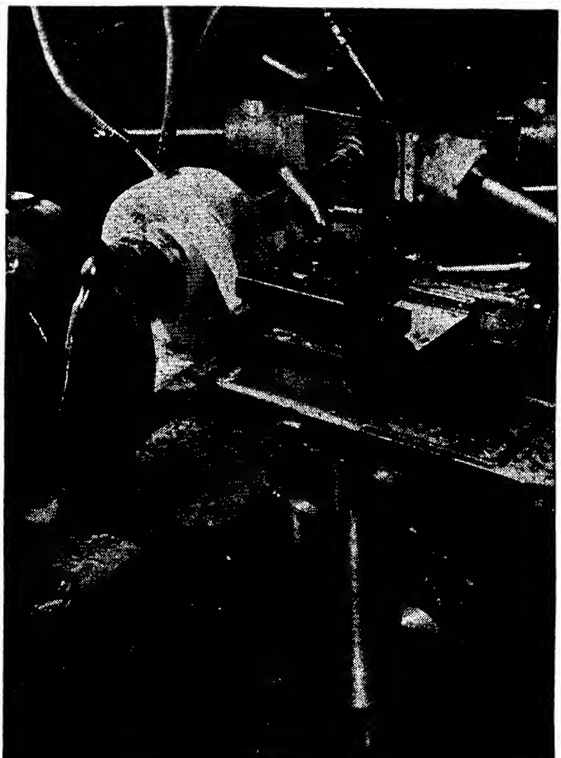


FIG. 44.—Another pump job on a turret.

cast pump part, an 11-13 stainless unit. Tool forms and chip breakers are standard for this work. The piece is roughed at a surface speed of 120 ft. per minute. Finish speed is 300 ft. per minute. Roughing feed is 0.021 in., and depth of cut is 0.250 in. Finish feed is 0.011 in. with depth of cut 0.015 in. The method of chucking the work and the arrangement of tools in the turret and sidehead are clearly shown.

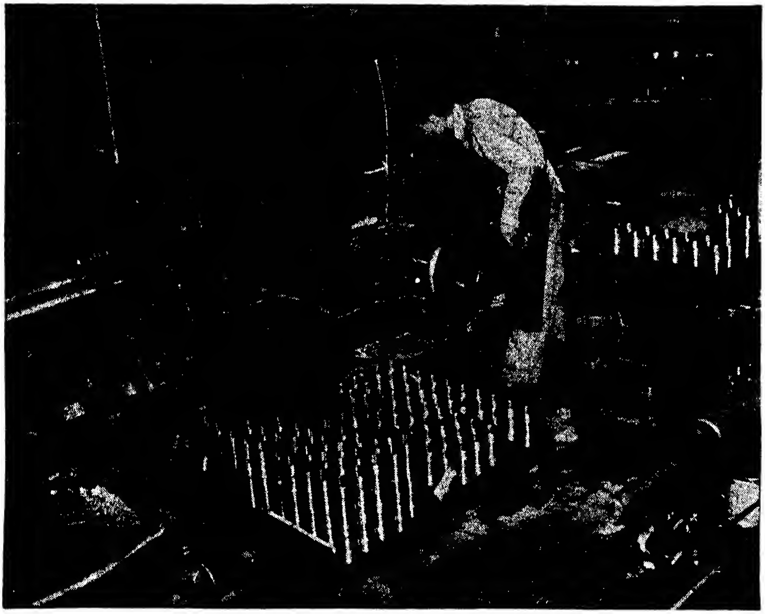


FIG. 45.—Machining liners for oil-well pumps.

Another piece of work in a vertical boring mill is represented in Fig. 43. The machine is a King boring mill with a pump part in the form of a forged ring, which is also of stainless steel. The ring is faced on one side, then turned over and faced on top, and then turned and bored. Roughing data are as follows: surface speed, 120 ft. per minute; feed, 0.020 in.; depth of cut, 0.218 in. Finish speeds and cut and feed rates are comparable with the data given for the job described above.

Another interesting class of work on pump parts is shown in Fig. 44. This is a stainless forging handled on a Gisholt turret lathe, which chucks the bore, turns the outside all over, and faces

shoulders and other surfaces. A finished piece is shown at the front of the machine in Fig. 44. Roughing cuts on this work at 120 ft. per minute are taken at 0.25 in. depth of cut and 0.021-in. feed.

Figures 45 and 46 illustrate another turret-lathe job, the machining of Moloy liners for insert liners in oil-well pumps. Quantity production on these liners is indicated in Fig. 45. Figure 46 is a close-up of the operation of machining the end of the work. The liners are S.A.E. 4120, 155,000 lb. tensile strength; the machining is done at the surface speed of 245 ft. per minute. Depth of cut is 0.032 in., and feed is 0.0105 in.

Using Old Equipment with Carbides.—In spite of the rapidly spreading adoption for machining of steels of sintered-carbide tools to increase productive capacity of machine tools, considerable misapprehension apparently still exists in industry as to the usability of older types of machine tools. It is pointed out by James R. Longwell of Carboloy Company, Inc., that there is no reason why older machines in good condition—such as turret lathes and boring mills—cannot be readily adapted to the use of carbide tooling. The fundamental consideration in old equipment, as well as in the new types of machine tools, is that the machine must be able to run—and to run smoothly—at that faster speed. Figures 46 and 47 show tools and tooling.

In the cutting of steels with carbides, the main objective to be kept in mind is that the cutting speed should be high enough to prevent the formation of a "built-up" edge. This means an average cutting speed in the neighborhood of 200 ft. per minute. (The lower the carbon, usually, the higher the speed.)

To check the adaptability of any piece of available machine-tool equipment to the use of carbides, the following general considerations suffice.

Power Requirement.—It takes more power to run at the higher speeds required—to remove metal at a faster rate. It takes more power, also, to cut steel than nonferrous metals or cast iron. Check the machine horsepower. Horsepower requirements may readily be calculated by the following formula: Hp per tool = depth of cut in inches × feed in inches × surface feet per minute × power constant.

The power constant varies from 6 to 10, depending on the steel to be cut, as follows:

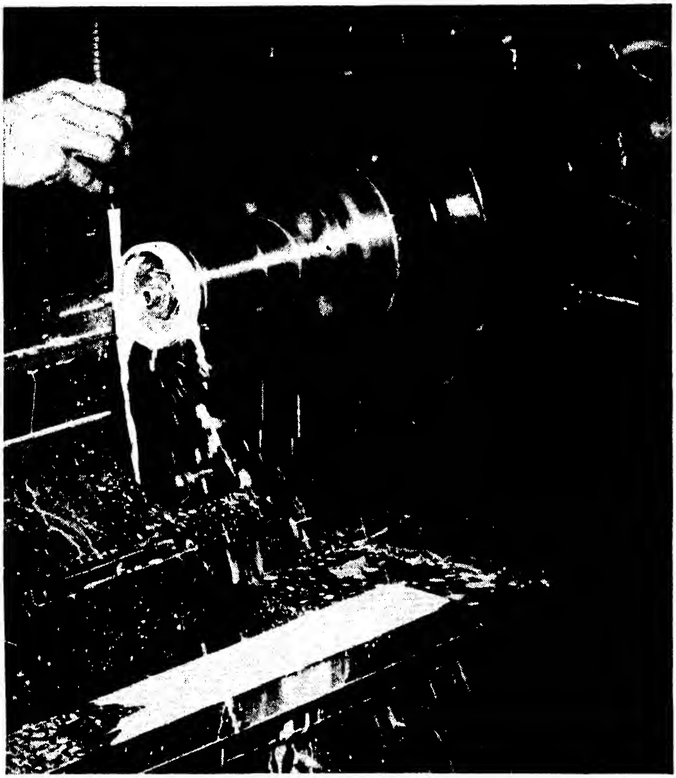


FIG. 46.—Close-up of machining end of liner.

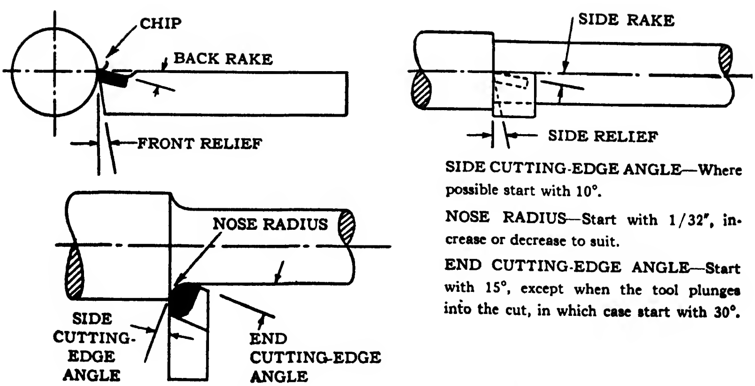


FIG. 47.—Using carbide tools on older machine tools.

Steel	Constant	Steel	Constant
1010–1025	6	3115–3130	8
1030–1095	8	3135–3450	9
1112–1120	6	4130–4820	9
X1314–X1340	8	5120–52100	10
T1330–T1350	9	6115–6195	10
2015–2320	7	Cast steel	9
2330–2350	9		

The power required to operate the machine at speed with tools not cutting must be added, of course, to obtain motor horsepower. This requirement is usually figured as 30 per cent of the horsepower required for cutting.

Power Transmission.—The power requirements for increasing machine speed to take full advantage of carbide tooling having been determined, belts, clutches, etc., should be checked for an ability to transmit the horsepower to the spindle. Clutch fingers should be adjusted to prevent slipping and stalling. If the machine is equipped with a flat belt, it is usually desirable to change to a V-belt drive and to make sure that the number of belts is adequate.

(Note: *If the machine stalls in the cut, loosen holding screws and remove tool from the cut to prevent breakage. Do not attempt to move work or try to back tool out of cut.*)

Centers.—The increased rate of stock removal at high speeds with cemented carbides makes it advisable to use an antifriction tail-stock center.

Spindles.—Spindles should be checked for adequate lubrication at the higher speeds at which they will operate.

Tool Posts and Holders.—Where machines have rocker tool plates, these should be eliminated and a solid support provided. A set of shims should also be provided to maintain the tool at proper cutting height.

Chip Room.—Provision must be available to handle the increased volume of chip production. Where openings in machine beds and around tool holders or blocks are too small to allow chips to get away, sheet-metal chutes frequently prove helpful in eliminating pockets and slots where chips are apt to clog. Chip breakers can be used, of course, where size of openings demands production of small chips.

Backlash.—Before steel is cut with sintered-carbide tools, machines should be checked for excessive clearances that would cause chatter at the higher cutting speeds. Worn bearings, slides, and ways must be replaced. It should be mentioned, however, that a certain amount of chatter can be corrected by the incorporation of negative rakes in the tools where it is found impossible or impractical to tighten the machine sufficiently to eliminate all vibration.

CHAPTER XXI

SPEED AND MACHINEABILITY

Cutting tools may be separated into two groups: carbon, which loses hardness at from 400 to 500°F., and high speed, which retains cutting hardness up to 1000°F. Carbon tools must not get over 300°F. in cutting, which means slower cutting speeds and plenty of coolant. The cutting tool faces three conditions in forcing itself through the metal: pressure, friction, and abrasion. Temperature may be varied by changing the coolant, the depth of cut, or the speed. Too high a speed softens the tool by heat while if the speed is too slow, it is ground away by abrasion. The economical speed must consider the metal removed, the cost of grinding the tool, and the time of making the change. These vary with the class of work being done. Taylor set 1½ hr. as the maximum time a tool should last on roughing work.

In lathe work more metal can generally be removed by using a coarse feed and slow speed than by higher speed and a fine feed. The heating of the work by the cutting action must also be considered, especially with regard to its dimensions after cooling. The best coolant for general operations on steel is a low-viscosity oil delivered at the cutting edge in large volume but with low velocity. The coolant should suit the work being done. Low speeds and heavy cuts require lubricant as well as cooling. The use of the proper coolant and lubricant gives a gain of about 15 per cent in cutting speed, on commercial types of steel. A low-viscosity cutting oil used straight gives a smoother cut and better finish than an emulsion.

The most widely used coolants are: Water mixed with alkali, fatty oil, mineral oil, soap or sulphur; fatty oil mixed with mineral oil, sulphur, kerosene, or turpentine; mineral oil mixed with kerosene; and kerosene. Use of the latter is not always safe from fire hazard.

The following table, XVII, is useful in selecting speeds and feeds (see also Figs. 48 and 49).

TABLE XVII.—CUTTING-SPEED CONVERSION TABLE
Surface Feet to r.p.m.

Diam., in.	Feet per minute														
	90	95	100	110	120	125	130	140	150	160	170	175	180	190	200
	Revolutions per minute														
1/16	5,502	5,808	6,114	6,725	7,337	7,643	7,948	8,560	9,171	9,782					
1/8	2,750	2,903	3,056	3,362	3,667	3,820	3,973	4,278	4,584	4,890	5,195	5,348	5,501	5,806	6,112
3/16	1,834	1,936	2,038	2,242	2,446	2,548	2,649	2,853	3,057	3,261	3,462	3,367	3,668	3,872	4,076
1/4	1,376	1,453	1,528	1,681	1,734	1,910	1,986	2,139	2,292	2,445	2,598	2,674	2,750	2,903	3,056
5/16	1,100	1,161	1,222	1,344	1,466	1,527	1,589	1,711	1,833	1,955	2,077	2,139	2,200	2,322	2,444
3/8	916	967	1,018	1,121	1,222	1,273	1,323	1,425	1,527	1,629	1,731	1,782	1,832	1,934	2,036
7/16	786	830	874	961	1,049	1,093	1,136	1,224	1,311	1,398	1,486	1,530	1,573	1,661	1,748
1/2	688	726	764	840	917	955	993	1,070	1,146	1,222	1,299	1,337	1,375	1,452	1,528
9/16	611	645	679	747	813	869	883	951	1,019	1,086	1,154	1,188	1,222	1,290	1,358
5/8	552	581	612	673	736	765	796	857	918	979	1,040	1,071	1,102	1,163	1,224
11/16	500	527	555	611	666	692	722	770	833	888	944	971	999	1,054	1,110
3/4	458	483	508	559	610	635	661	711	762	813	864	889	914	965	1,016
13/16	427	450	474	521	569	593	616	664	711	758	806	830	853	901	948
7/8	392	416	438	482	526	548	569	613	657	701	745	767	788	832	876
15/16	366	387	407	448	488	509	529	570	611	651	692	712	733	773	814
1	344	363	382	420	458	478	497	535	573	611	649	669	688	726	764
1 1/16	323	341	359	395	431	449	467	503	539	579	610	628	646	682	718
1 1/8	306	324	340	374	408	425	442	476	510	544	578	595	612	646	680
1 3/16	290	306	322	354	386	403	419	451	483	515	547	564	580	612	644
1 1/4	274	291	306	337	367	383	398	428	459	490	520	536	551	581	612
1 5/16	262	276	291	320	349	351	378	407	437	466	495	509	524	553	582
1 3/8	250	264	278	306	334	348	361	389	417	445	472	487	500	528	556
1 7/16	239	251	265	292	318	331	345	371	398	424	451	464	477	504	530
1 1/2	230	241	254	279	305	318	330	356	381	406	432	445	457	483	508
1 9/16	220	232	244	268	293	305	317	342	366	390	415	427	439	464	488
1 5/8	212	222	234	257	281	293	304	328	351	374	398	410	421	445	468
1 11/16	203	215	226	249	271	283	294	316	339	362	384	396	407	429	452
1 3/4	196	207	218	240	262	273	283	305	327	349	371	382	392	414	436
1 13/16	190	200	211	232	253	264	274	295	317	338	359	369	380	401	422
1 7/8	184	194	204	224	244	255	265	286	306	326	347	357	367	388	408

$1\frac{15}{16}$	177	187	197	217	236	246	256	276	296	315	335	345	355	374	394
2	172	181	191	210	229	239	248	267	287	306	325	334	344	363	382
$2\frac{1}{8}$	162	171	180	198	216	225	234	252	270	288	306	315	324	342	360
$2\frac{1}{4}$	153	162	170	187	204	213	221	238	255	272	289	298	306	313	340
$2\frac{3}{8}$	145	153	161	177	193	201	209	225	242	258	274	282	290	306	322
$2\frac{1}{2}$	138	145	153	168	184	191	199	213	230	245	260	268	275	291	306
$2\frac{5}{8}$	131	138	145	160	174	181	189	203	218	232	247	254	261	276	290
$2\frac{3}{4}$	125	132	139	153	167	174	181	195	209	222	236	242	250	264	278
$2\frac{7}{8}$	119	125	132	145	158	165	172	185	198	211	224	231	238	251	264
3	114	121	127	140	152	159	165	178	191	203	216	222	228	241	254
$3\frac{1}{8}$	110	116	122	134	146	153	159	171	183	195	207	214	219	232	244
$3\frac{1}{4}$	105	111	117	129	140	146	152	164	176	188	199	205	211	222	234
$3\frac{3}{8}$	102	108	113	124	136	141	147	158	170	181	192	198	203	215	226
$3\frac{1}{2}$	98.1	104	109	120	131	136	142	153	164	174	186	191	196	207	218
$3\frac{5}{8}$	94.5	99.8	105	116	126	131	137	147	158	168	179	184	189	200	210
$3\frac{3}{4}$	91.8	96.9	102	112	122	128	133	143	154	163	175	179	184	194	205
$3\frac{7}{8}$	88.6	93.6	98.5	108	118	123	128	138	148	158	167	172	177	186	197
4	86.0	90.8	95.6	105	115	120	124	134	143	153	163	167	172	182	191
$4\frac{1}{4}$	80.8	85.3	89.8	98.8	108	112	117	126	135	144	153	157	162	171	180
$4\frac{1}{2}$	76.3	80.6	84.8	93.3	102	106	110	119	127	136	144	148	153	161	170
$4\frac{3}{4}$	72.4	76.4	80.4	88.4	96.9	101	105	113	121	129	137	141	145	153	161
5	68.8	72.6	76.4	84.0	91.7	95.5	99.3	107	115	122	130	134	138	145	153
$5\frac{1}{4}$	65.4	69.1	72.7	80.0	87.2	90.9	94.5	102	109	116	124	127	131	138	145
$5\frac{1}{2}$	62.5	65.9	69.4	76.3	83.3	86.8	90.2	97.2	104	111	118	121	125	132	139
$5\frac{3}{4}$	59.8	63.1	66.4	73.0	80.0	83.0	86.3	93.0	99.6	106	113	116	120	126	133
6	57.2	60.5	63.6	70.0	76.3	79.5	82.7	89.0	95.4	102	108	111	114	121	127
$6\frac{1}{4}$	55.0	58.0	61.1	67.2	73.3	76.4	79.4	85.5	91.7	97.7	104	107	110	116	122
$6\frac{1}{2}$	52.8	55.8	58.7	64.6	70.4	73.4	76.3	82.2	88.1	93.9	100	103	106	112	117
$6\frac{3}{4}$	50.9	53.8	56.6	62.3	67.9	70.8	73.6	79.2	84.9	90.6	96.2	99.0	102	108	113
7	49.1	51.9	54.6	60.1	65.5	68.3	71.0	76.4	81.9	87.4	92.8	95.6	98.3	104	109
$7\frac{1}{4}$	47.4	50.1	52.7	58.0	63.2	65.9	68.5	73.8	79.1	84.3	89.6	92.2	94.9	100	105
$7\frac{1}{2}$	45.8	48.4	50.9	56.0	61.1	63.6	66.2	71.0	76.4	81.4	86.5	89.1	91.6	96.7	102
$7\frac{3}{4}$	44.3	46.7	49.2	54.1	59.0	61.5	64.0	68.9	73.8	78.7	83.6	86.1	88.6	93.5	98.4
8	43.0	45.4	47.8	52.6	57.4	59.8	62.1	66.9	71.7	76.5	81.3	83.7	86.0	90.8	95.6

Both Fig. 48 and conversion Table XVII will be found useful in somewhat different ways. Both can be used in connection with Fig. 49.

Drill, milling cutter, or work r.p.m. can be found quickly by means of this chart. It also affords a method for determining

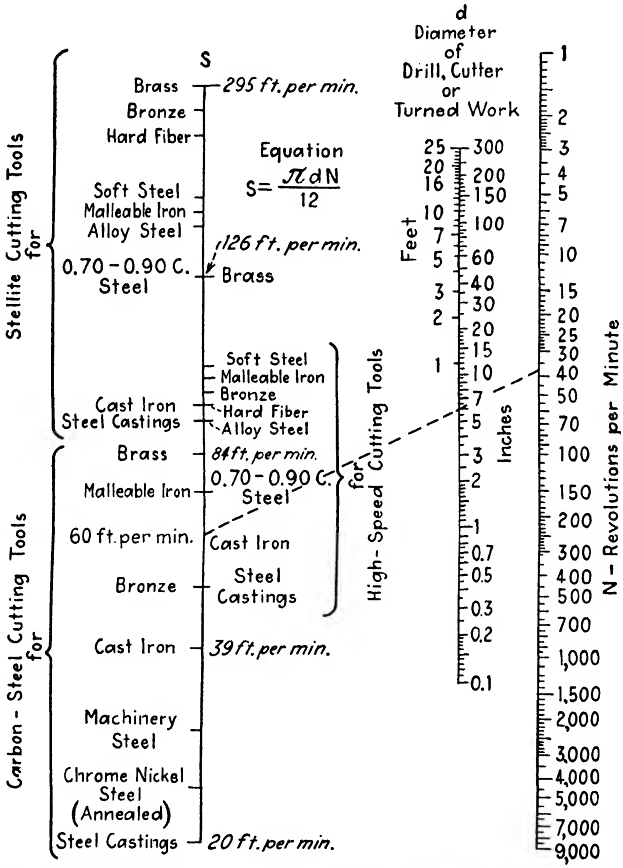


FIG. 48.—Cutting speed chart. (*Originated and computed by L. C. Simmonds.*)

cutter or tool material and required changes in cutter material for varying speeds, and is read by placing a straightedge to satisfy two known factors in order to obtain the third. (The chart may of course be altered to suit individual conditions simply by reallocating the values on line *S*. The values given

are average—when taking heavy cuts decrease the r.p.m. found; for light cuts *vice versa*.)

Example.—A high-speed cutter is to be used in a lathe or boring mill to machine a cast-iron pulley 6 in. in diameter. One point of intersection is "cast iron," lying within the "high-speed cutting tool" bracket; the second is 6 on the d scale. The N scale then reads 38. Computation by formula will give 38.2, showing an error of but 0.2 r.p.m.

MACHINE SPEED AND FEED CHART

Instructions for using the chart are:

1. Select feed and depth of cut to suit stock to be removed, stiffness of work, and machine. Use large tool radius for heavy cuts.

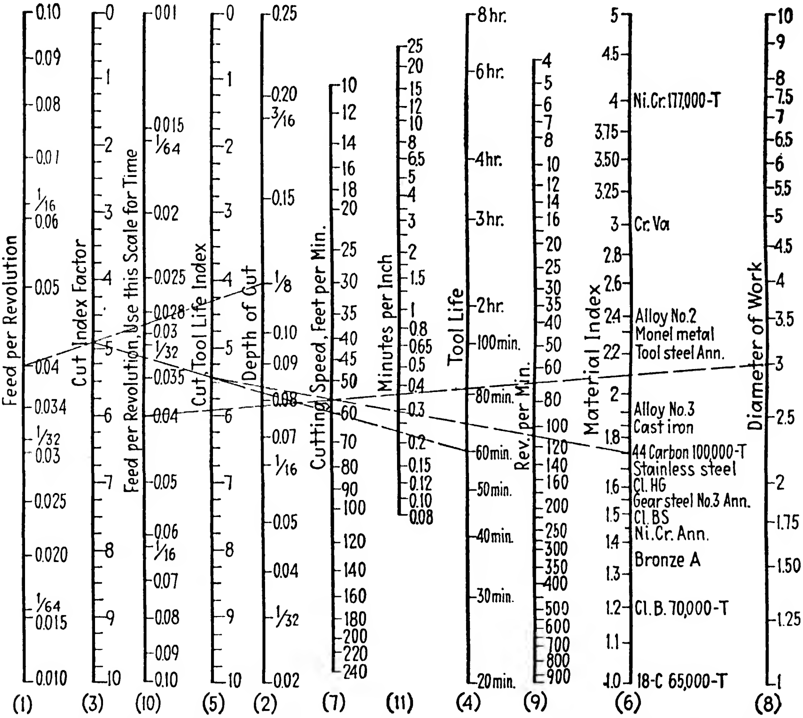


FIG. 49.—Chart for determining machining feeds and speeds. (*Prepared by I. M. McGonnell.*)

2. Run a line from feed (1) to cut (2) and get intersection on (3).
3. Run a line from intersection (3) to tool life (4) and get intersection on (5).
4. Run a line from intersection (5) to material (6) and get cutting speed (7).

5. Run a line from cutting speed (7) to diameter (8) and get r.p.m. (9).
6. Run a line from r.p.m. (9) to feed (10) and get minutes per inch (11).

For example, take the following combination: A shaft, 3.0 in. diameter, 0.44 carbon steel, 100,000 tensile strength, 1/8 in. depth of cut, 0.04 in. feed, and tool life 1 hr. Place a ruler on 0.04 (column 1) and 1/8 (column 2) and the intersection in column 3 is 4 7/8. Place the ruler on 4 7/8 (column 3) and

TABLE XVIII.—MATERIALS MACHINED WITH KENNAMETAL

Material to be cut	Type of cut	Grade	Suggested speed, ft. per min.
Carbon, nickel, nickel-chrome, molybdenum, chromium, and chrome-vanadium steels of usual ranges	Heavy roughing on forged or rolled steel	KM	See chart below
	Heavy roughing on cast steel	K2S	
	Medium cuts	KM or K3H	
	Finish cuts	K3H or K4H	
	Precision boring	K5H	
High-manganese steels	General use	K2S	35– 100
S.A.E. 52100 (400–450 Brinell)	Roughing	KM	80– 100
	Finishing	K3H	100– 125
High-speed steel (annealed)	General use	K3H	120– 200
Stainless steel 18–8	Roughing	KM	150– 250
	Finishing	K3H	200– 300
	Precision boring	K5H	300– 800
Cast iron	Heavy roughing	K2S	150– 300
	General use	K6	200– 350
	Finishing	K6	250– 400
Malleable iron	General use	K4H or K6	350– 700
Copper alloy iron	General use	K4H or K6	200– 400
Brass	General use	K6	500–1000
Aluminum bronze	General use	K6	250– 500
Aluminum and magnesium alloys	General use	K6	500 or over
Monel metal (K or S)	General use	K3H	70– 90
Nonmetallics	Heavy roughing	K2S	400 and over
	General use	K6	400 and over

For steels of common specifications as noted in the first group in the above table, speeds should be selected according to hardness.

60 (column 4) and the intersection in column 5 is 5½. Place the ruler on 5½ (column 5) and 0.44 carbon (column 6) and the intersection in column 7 is 57. Place the ruler on 57 (column 7) and 3.00 (column 8) and the intersection in column 9 is 70. Place the ruler on 70 (column 9) and 0.040 (column 10) and the intersection in column 11 is 0.37 minute per inch of cut.

TABLE XIX.—SUGGESTED SPEEDS FOR VARIOUS RANGES OF HARDNESS

Hardness of work			Suggested speed
Rock. C	Brinell	Scler.	Surf. ft. per min.
65	682	93	20– 30
60	601	83	30– 50
55	545	75	50– 60
51	495	69	60– 80
45	427	62	80–100
40	370	54	100–150
35	323	46	150–220
30	276	42	220–300
25	249	38	300–400

For lower hardnesses use correspondingly higher speeds.

In general, the lower range of suggested speeds should be selected for use with heavier feeds, the higher range for lighter feeds.

In use, such a chart must be considered basic only and should satisfactory results not be obtained, a check-up should be made of such probable causes as materials, coolant, composition, and condition of tools, shape of cutting edge, tool mounting, or chip interference.

Using Carbide Tools.—Carbide tools vary both as to hardness and their resistance to abrasion. For this reason it is best to consult the makers of the kind of carbide used, regarding its selection. Kennametal suggests the following concerning its tools.

Table XVIII gives good general suggestions as to the best speeds to be used in machining different materials and the type of Kennametal best suited for it. At the bottom is a supplementary table especially useful where very hard materials must be machined. It also gives working comparisons of the ratings of the different scales, Rockwell C, Brinell, and scleroscope.

MACHINEABILITY OF METALS

We have as yet no satisfactory method of determining, or even estimating at all accurately, the machineability of metals

or other substances used in machine building. Hardness plays an important part, and we know that a common steel which shows a Brinell hardness of 400 will be much harder to cut than one which shows but 200. The same applies to cast iron and some other substances. But this does not hold true in all steels as the alloys used affect the cutting qualities very differently from the hardness. A steel with a large percentage of manganese is not hard when tested with Brinell, but it is almost impossible to cut it with ordinary tools.

The only reliable tests of machineability, according to H. W. Graham, general metallurgist of the Jones & Laughlin Steel Co., is to cut a piece in a machine, presumably a lathe, and note the life of the tools.

Some of the nonferrous metals, such as copper, are not hard but are difficult to cut satisfactorily, owing to the nature of the metal itself. Many nonmetallic substances, such as bakelite and other plastics or fibers, are also very hard on tools, owing largely to the abrasive qualities of the material. This grinds the cutting edge away rapidly and soon dulls the tool. For material of this kind the harder cutting alloys, such as Stellite and tungsten or tantalum carbide, have many advantages. In some cases tools tipped with diamonds are used very successfully in machining this material. Data from experience with a variety of materials follow:

Top Range of Hardness.—From study and tests a few general facts have been established:

Generally speaking, the top range of hardness at which metals can be machined with high-speed steel tools is about 375 Brinell. There are some exceptions to this rule among the high-chromium or high-manganese steels.

For a given material the machineability may be comparatively high when the material is in its extreme soft state. The machineability may fall as the hardness is increased through the intermediate range, but will, of course, rise as the hardness is further increased.

As the machineability rises, cutting speeds must be decreased. Feeds, on the other hand, are much less affected and may be kept at a fairly constant level.

A summary of the results of a series of tests by Prof. O. W. Boston, on machining metals, is given in the diagram in Fig. 50.

The three lower lines show the horsepower required to remove 1 cu. in. of metal per minute, from the metals listed. The upper line shows the time required, in fractions of a minute, for a ¼-in. drill to penetrate 0.10 in. This drill had a helix angle of 24 deg. and was fed by a constant load of 93.75 lb.

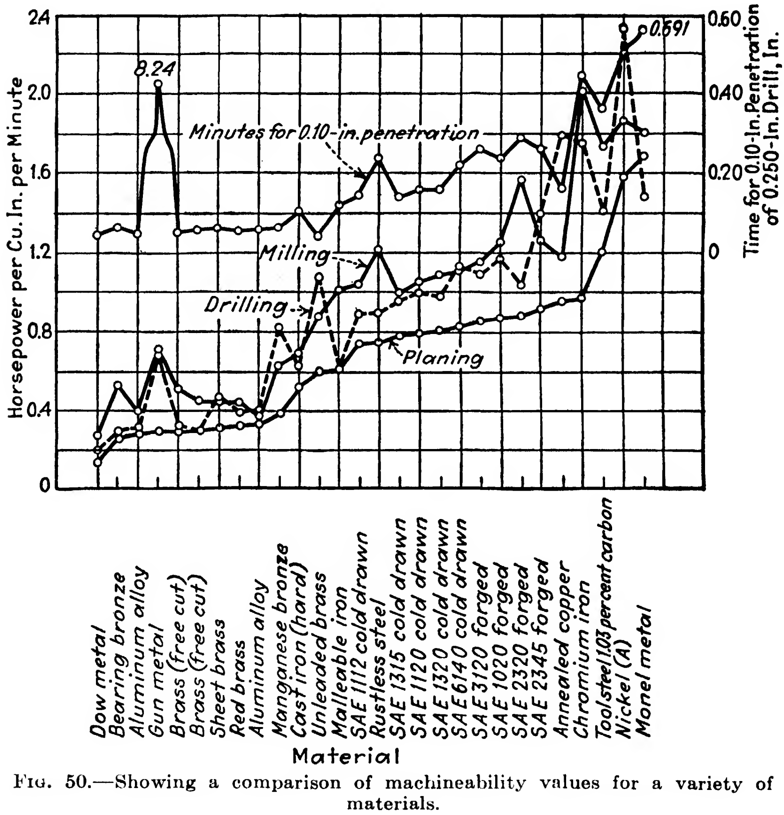


FIG. 50.—Showing a comparison of machineability values for a variety of materials.

The drill used in the lower-line test was ¾ in. in diameter, had a helix angle of 30 deg., a speed of 152 r.p.m., and a feed of 0.012 in. per revolution.

The planer tool used was ½ in. wide, cut on the end, had a 15-deg. front rake angle depth of cut was 0.010 in., speed 20 ft. per minute.

The milling cutter was 0.25 in. wide, had a 15-deg. rake angle, depth of cut was 0.125 in., and had a feed of 0.010 in. per tooth,

The power required varies with the distance below the surface. It is smallest at the surface, increases with the depth for a short distance, and again decreases to a depth of $\frac{1}{8}$ in.

The diagram makes a convenient reference concerning the comparative machineability of the different metals.

Chatter in Metal Cutting.—To those having experience with the cutting of metals "chatter" is a familiar phenomenon. It can be defined, says Carl J. Oxford, as synchronized vibrations that are set up in the cutting tool, the work, the machine or a combination of vibrations in all of these elements.

The cause of these vibrations, or chatter, is usually because of the lack of rigidity. This lack of rigidity permits the affected members to deflect under the cutting strains until the load builds up to a point where the material to be cut gives way. As the material is torn away, the strains are lessened and the deflected member springs back to its natural position. But the resistance begins to build up again at once, causing another deflection. This process, when rapidly repeated, sets up the vibrations that we know as chatter. This results in a hammering action of the cutting edge, or edges, against the work. This hammering may cause the cutting edges to chip out in small pieces, or the body of the tool to fracture. Deflections, continued over a period of time, may also cause failure of the tool or of the machine by fatigue.

Investigators have attempted to show that metal can be cut with less expenditure of power if chatter is present. While this is a possibility because of the hammering action referred to above, it is hardly an argument in favor of chatter. The disadvantages in the way of rough work and premature tool failures by far outweigh any power saving. The elimination of chatter is, therefore, necessary for successful metal cutting. The first step is to definitely locate the cause and then to make such adjustments in the set-up as will cure the trouble.

Looseness of moving parts of the machine is one common obvious cause. This looseness may be due to wear or to careless adjusting. The remedy is to replace worn parts that cannot be adjusted and to take out all "play" where adjusting can be done. The rigidity of the machine itself is most important. The tool spindle, cutter arbor, and other driving parts must be of sufficient strength so that they will not deflect under the cut to be taken.

Large diameter arbors for milling cutters, and rigid machines are essential in all milling operations. Substantial holding fixtures and adequate support of the work are also of vital importance. These precautions are necessary in all metal-cutting operations where any considerable strains are involved.

The proper design of cutting tools for the work to be performed must be considered as the next factor affecting chatter. Here the conditions vary widely, owing to differing depths of cuts, widths, lengths, and diameters of the tools, areas of surfaces to be machined, materials, and lubrication, so it is often necessary to study each individual application in order to obtain the best results. Some general methods of eliminating chatter by means of tool designs are suggested below:

Drills.—When drills chatter, the cause usually is to be found in torsional deflection. The longer the drill, in proportion to its diameter, the greater the danger of deflection and chatter. Where a shorter drill cannot be used the remedy is to increase its cross section at points where the greatest resistance to torsion is offered. This must, however be combined with adequate chip space.

Reamers.—Chatter of reamers is sometimes caused by too much area of contact between the reamer and the work; but the more common cause is the use of straight-fluted reamers instead of helical-fluted ones. Straight-fluted reamers should always have unevenly spaced cutting edges so as to break up any tendency to synchronize the slipping around from the mark of one tooth to that of the next. Too much clearance behind the cutting edges may also cause these edges to bite into the work and so cause chatter. Helical-fluted reamers are to be preferred where any danger of chatter exists.

Milling Cutters.—The elimination of chatter from milling operations is somewhat more difficult because of the variety of surface to be machined. These surfaces may vary from the cutting of thin sections where there is almost a point contact between cutter and work, to the milling of wide, flat surfaces where the area of contact is large.

The spacing of teeth in milling cutters must be chosen accordingly. This spacing should be such that two or more teeth are engaged in the work at all times. In this way the hammering actions of individual teeth entering and leaving the cut are largely neutralized.

If the cut is of such nature that two teeth cannot engage the work at the same time, cutters with helical teeth are necessary. Because of the angle of the cutting edges they will not strike the work simultaneously across their full width, but will engage gradually as the cutter rotates giving a shearing cut. A much smoother action results.

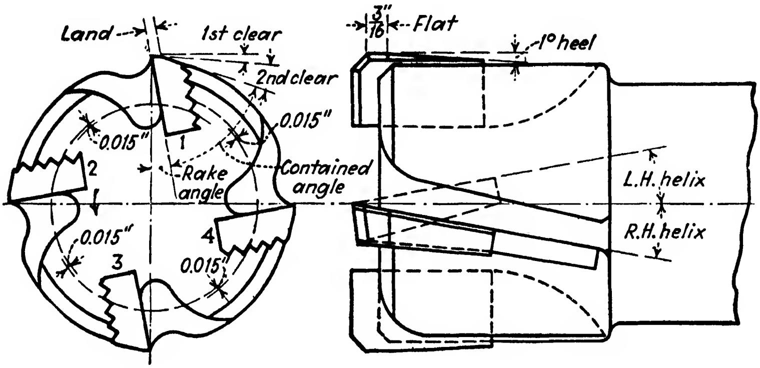


FIG. 51.—Cutting and clearance angles are shown on this adjustable reamer with offset serrations.

It is always profitable to eliminate chatter from metal-cutting operations, because by doing so we not only obtain better work, but also get longer tool life and produce more finished pieces in a given time.

BORING-TOOL DESIGN

The following designs of boring tools, such as in Fig. 51, and the data as to cutting angles, allowances for metal to be removed, and cutting are the result of the experience of R. R. Weddell, who spent much time in their development. The tables give the number of blades to be used, the cutting angles for different materials, allowances of metal for roughing and finishing, and cutting speeds for different kinds of tools on a variety of materials (see Tables XX to XXIII).

None of these figures must be considered as meeting all requirements but they are to be used as a starting point, or general guide, in new jobs. The best speed and feed for any job depend on the power available, the rigidity of the tool spindle or jig, the method of piloting, the structure of the work, the machineability of material, and other factors.

TABLE XX.—NUMBER OF BLADES IN BORING CUTTERS

Roughing

1½ to 2¾ in. diameter	4 blades
2¾ to 4¼ in. diameter	6 blades
4½ to 10 in. diameter	8 blades
10 in. diameter and up	10 blades

Finishing

1½ to 2½ in. diameter	6 blades
2½ to 3 in. diameter	8 blades
3 to 4 in. diameter	10 blades
4 to 5 in. diameter	12 blades
5 to 8 in. diameter	14 blades
8 to 10 in. diameter	16 blades
10 to 12 in. diameter	18 blades
12 in. diameter and up	20 blades

TABLE XXI.—ALLOWANCES FOR ROUGHING AND SEMI-FINISHING

Diameter	Roughing, in.	Semi-finishing, in.
2 in. and under	0.025	0.005
2 to 10 in.	0.030	0.005
10 in. and up	0.060	0.010

In addition to knowing the allowances for boring cuts, as given in Table XXI, the feed, or advance, of the tool must be considered. A fair average feed, for either roughing or finishing work, is 0.010 in. per blade per revolution. This is equivalent

TABLE XXII.—CUTTING SPEEDS FOR BORING TOOLS

	Roughing				Finishing			
	H.S.S.	Super-H.S.S.	J-Stellite	T.C.	H.S.S.	Super-H.S.S.	J-Stellite	T.C.
Copper Brass	120	150	200	300	150	200	250	400
Cast iron Bronze	50	75	100	150	60	90	110	200
Semi-steel cast	50	75	...	....	60	90		
Steel cast	40	65	...	....	50	75		
Machine steel (0.15–0.20)	60	...	...	....	75			
Steel (0.30–0.40)	50	75	...	....	60	90		
Alloy steel	40	60	...	....	50	75		
Malleable iron	60	85	120	175	75	100	130	200
Aluminum	250	300	400	1000	300	400	500	1000

TABLE XXIII.—CUTTING ANGLES FOR BORING TOOLS

Diameter, in.	Steel								Cast iron or brass								Aluminum							
	Rougher				Finisher				Rougher				Finisher				Rougher				Finisher			
	Rake	Clearance	Land	Helix	Rake	Clearance	Land	Helix	Rake	Clearance	Land	Helix	Rake	Clearance	Land	Helix	Rake	Clearance	Land	Helix	Rake	Clearance	Land	Helix
1½	0	6°	1/32	5°	0	6°	1/32	5°	0	4°	1/16	0	0	4°	1/16	0	0	6°	1/32	10°	0	6°	1/32	5°
2	0	6°	1/32	5°	0	6°	1/32	5°	0	4°	1/16	0	0	4°	1/16	0	5°	6°	1/32	10°	5°	6°	1/32	10°
2½	0	6°	1/32	10°	0	6°	1/32	10°	0	4°	1/16	0	0	4°	1/16	0	10°	6°	1/32	15°	10°	6°	1/32	15°
3	5°	6°	1/32	10°	0	6°	1/32	10°	0	4°	1/16	0	0	4°	1/16	0	15°	6°	1/32	15°	10°	6°	1/32	15°
4 up	10°	6°	1/32	10°	0	6°	1/32	10°	0	4°	1/16	0	0	4°	1/16	0	15°	6°	1/32	15°	10°	6°	1/32	15°

to the feed per tooth in milling cutters. On combination tools, with some large diameters, this may take more power than is available. Cutting speeds are shown in Table XXII and cutting angles in Table XXIII.

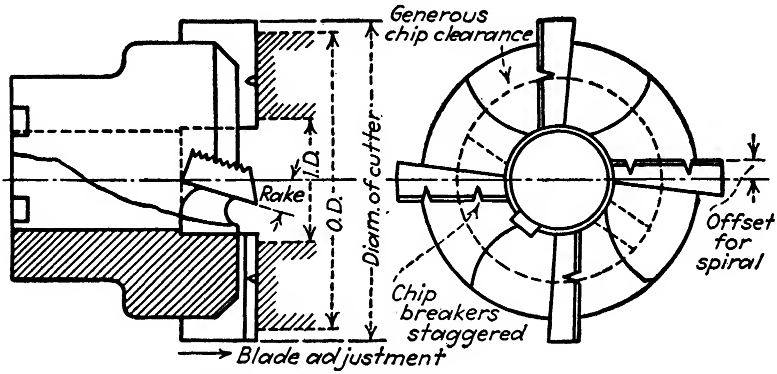


FIG. 52.—Cutting angles and general design for a facing head are indicated.

Facing Cutters.—Facing involves certain considerations of tool design not found in other metal-cutting operations. A faced surface may be machined by a single-point tool fed across it, or it may be finished with a wider tool brought into position

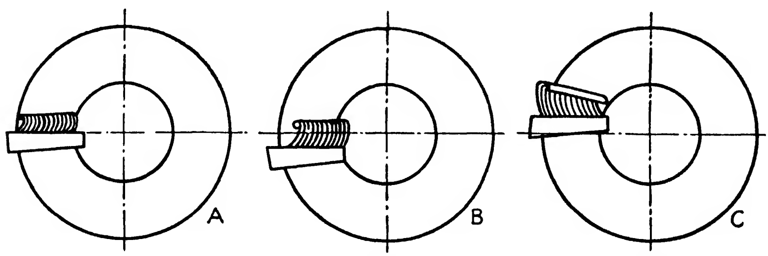


FIG. 53.—At *A*, with the blade on center and no spiral action, the chip piles up on the blade. At *B*, with the blade back of center, the spiral action crowds the chip toward the center. At *C*, with the blade ahead of center, the spiral action crowds the chip out from the center.

to cut the whole surface at once. In multiblade facing heads, several wide cutters operate at one time.

The cutting angles of a facing head in relation to the axis of the cutter may be regarded as opposite to those of a boring cutter. In Fig. 52, the rake angle is on the periphery of the cutter while the spiral angle is measured in the plane of the face. A positive rake is recommended for most materials, cast iron as

well as steel, to reduce the heavy load required for feeding. This may be modified if the tool tends to chatter or dig. The spiral angle on the face of the tool should be negative; that is, the cutter blade should be set ahead of center. This will cause the chip to crowd out and away from the center. Figure 53 shows the spiral action for blades of different settings in relation to the radial center line.

The adjustment of facing blades as in other cutters should be in the direction of feed; that is, they should be moved forward from the face of the body instead of radially, as in a boring head, where sizing the diameter is all important.

Facing calls for heavy pressure against the surface. The total width of chip is considerable, and all refinements of tool design should be considered to gain the maximum cutting efficiency. Fewer blades should be used than in a boring tool. The cuts, especially if wide, demand a heavy pressure for feeding, and it is obvious that the more blades there are, the more power will be required to take the cut. Therefore, facing heads should have comparatively few blades. Better results will be obtained, too, by having an odd number of blades in the cutter. A few blades will make the action truly a cutting one. If there are many, the feed means on the usual machine tool is not adequate. Facing with a many-bladed cutter tends toward a scraping operation, which quickly dulls or nicks the teeth and will not result in a smooth finish.

Chip Clearance.—Ample provision should be made in a facing cutter for chip clearance. Where the chip is wide and considerable metal is being cut, the body is generously grooved, as shown in Fig. 52. Nicks in the teeth, staggered, break up the chip and assist in its movement from under the face of the cutter blade.

Facing heads operate at the same cutting speeds as boring tools. The feed is a trifle less but still great enough to insure a positive cutting action. Speed and feed tables for facing with high-speed steel are shown in Table XXIV.

As stated previously, facing heads require considerable power to function satisfactorily. Therefore amply large keyways should be provided. Keys should be located against a solid shoulder and be driven through an end keyway.

Facing heads are made with the bore design as in Fig. 54,

or may have a solid shank; or they may be further fitted with pilots for facing off the top of a boss, the cutter locating in a previously bored hole.

TABLE XXIV.—CUTTING SPEEDS AND FEEDS

Cutting Speeds

	Feet per Minute
Brass	120
Cast iron	50
Mild steel (0.10–0.20 carbon)	60
Steel (0.30–0.40 carbon)	50
Alloy steel	40
Steel casting	40
Malleable iron	60
Aluminum	250

Cutting Feeds

	Inch per Revolution
To 3 in. diameter	0.015
3 to 6 in. diameter	0.010
6 in. diameter and up	0.005

Facing heads are successfully combined with boring heads in many cases. An odd combined facing and boring tool is shown in Fig. 54 for boring a blind hole. Three boring blades and one wide facing blade are used. The latter is set on a radial line and passes across the center. This permits it in one revolution to sweep the whole bottom surface of the blind hole. The tool floats, the drive being through two pins fitting loosely into holes in the drive spindle. The screw shown is set to the desired diameter when grinding to allow for gaging the odd number of blades. The screw is removed when the cutter head is in use.

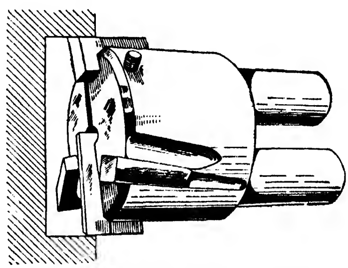


FIG. 54.—Boring and facing.

Hollow Mills.—Hollow mills are boring heads turned inside out and are used for milling bosses or projections. They are multiblade tools which supplant the usual single-point box tools.

As shown in Fig. 55, all considerations of cutting angles are reversed as compared with boring cutters. While the cutter blades must have rake, the slant of the blade is opposite. The rake angle pushes the chip away from the center and prevents

clogging. Since rake reduces the body strength, small cutters are often used without it. A slight helix angle is generally incorporated when using inserted blades. This, too, is necessarily omitted on the smaller cutters. The outline of the blade is similar to that of a boring head, except that it generally has a

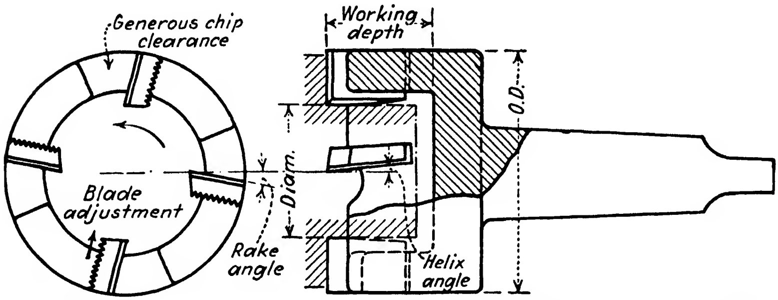


FIG. 55.—Chip clearance, rake, and helix angles are shown for a typical mill.

sharp corner. The blade, beyond the short straight lip, is relieved on its inside edge.

Many types of inserted-blade hollow mills are offered commercially. They include types in which all of the blades may be unlocked and moved inward together and those in which the blades are removed separately, reinserted, and reground to size.

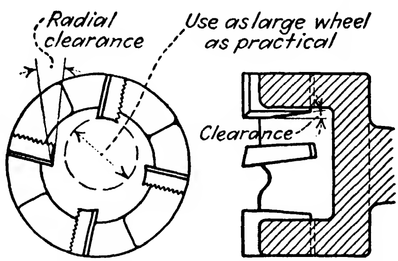


FIG. 56.—Strength of the body and wheel clearance limit the number of blades that it is practical to use.

The former type is somewhat simpler to maintain as the blades may be reground when off the cutter. For accurate work, however, the blades must be ground after adjustment and lock-up in the cutter.

The grinding operation is rather unusual. The cutting edges are ground by using an internal grinding attachment on a universal tool grinder. The cutter is mounted in the conventional manner in the universal work head adjusted to obtain adequate

clearance. The periphery of the internal grinding wheel backs off the blades. The wheel should be as large in diameter as practical without interfering with the next blade. The outline angles are further shown in Fig. 56.

While a hollow mill is a reversed boring head, during the major portion of its cut, at the finish of the operation it generally faces a shoulder of some sort. Fewer blades are required for facing. Also the number of blades is limited, as they interfere with grinding, as shown in Fig. 56. Three, four, or six blades are sufficient to give increased production over a single-point tool.

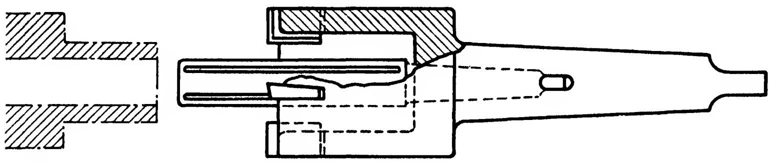


FIG. 57.—A pilot located in the hollow is sometimes useful to steady the cut.

If there is no excessive stock to be removed, the cutting speeds and feeds for hollow milling, roughing or finishing, are identical with those for boring, although the feed should be reduced at the end of the cut during the facing operation. Roughing cuts in hollow milling refer to cuts taking about $\frac{1}{8}$ in. on the side and finishing to about $\frac{1}{64}$ in. on a side. The feeds are about 0.010 in. per blade, the same as for boring tools.

Body designs of hollow mills have the same range as boring tools. They may be of the solid shank type, as in Fig. 55, which may be made to guide itself by grinding its outside diameter to locate in a piloting bushing or a separate pilot may be fitted within the tool to guide it in a previously bored hole, as shown in Fig. 57. Larger hollow mills are best made of the shell type, that is, with bore, and are located on a separate arbor.

SOME PECULIARITIES OF ALUMINUM ALLOYS

Although the use of aluminum alloys is increasing in general manufacture, few people realize the peculiarities encountered in machining these materials. The experiences of Roland V. Hutchinson, production engineer of General Aviation Corporation, are of interest. The alloys used considerably in aircraft work and to a great extent in other lines as well are: alloy 17ST, a strong alloy of the dural type, and the casting alloy, 195HT 4,

which contains about 4.5 per cent copper as a hardener, and a 13 per cent silicon-aluminum alloy. The latter casting material is used extensively for complex fittings in seaplane hulls.

Alloy 17ST has the property of growing in dimension when machined. Evidently the degree of internal stressing from the quench is very great, for when slabs are cut up they change remarkably in dimensions. For example, Fig. 58 shows a hinge

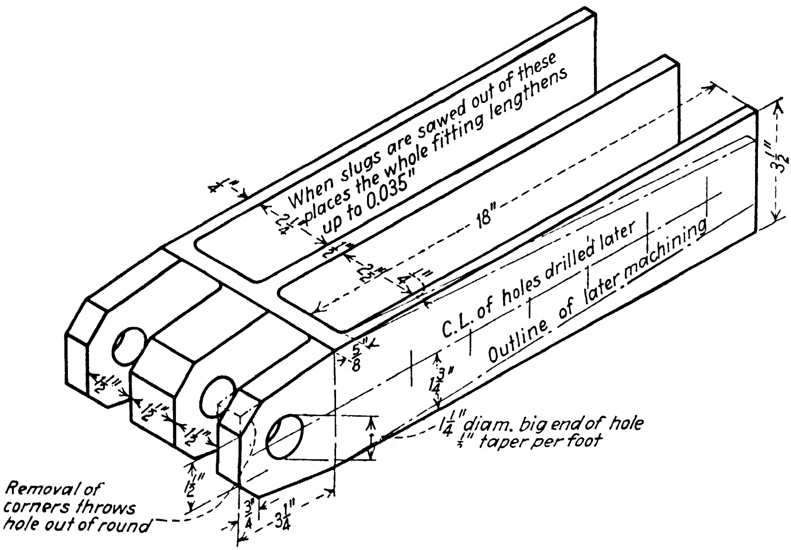


Fig. 58.—Unusual growth during machining can be expected from the aluminum alloys. This 17ST hinge fitting, made of hot-rolled bar, lengthened and warped generally, is one requiring care in the sequence of operations.

fitting made from hot-rolled bar $6\frac{7}{8}$ by $3\frac{5}{8}$ in. in cross-section, with $\frac{3}{4}$-in. radius corners, originally about 18 ft. long and received in the heat-treated condition. After cutting to length and face milling the four sides, the slugs indicated were hand-sawed out, whereupon the remaining tines elongated between 0.028 and 0.035 in. consistently, in addition to a general warpage of the fitting. In the first groups of fittings made, the "holes drilled later" were instead drilled first, fortunately $\frac{1}{16}$ in. undersize, and it was just possible to clean them up to proper dimension and location. Subsequent fittings were finally drilled after sawing.

Many aircraft subassemblies are now connected by tapered bolts. A taper of $\frac{1}{2}$ in. per foot is used. With alloy fittings and

steel bolts bearing in the dural, accuracy of fit of the conical surfaces is important. Removal of corners as indicated, *after* holes are finish-reamed, is fatal to good bearing. *Such holes should be finished last.*

In Fig. 59 is shown another block made from the same kind of raw stock. This part, while ultimately lightened, does not

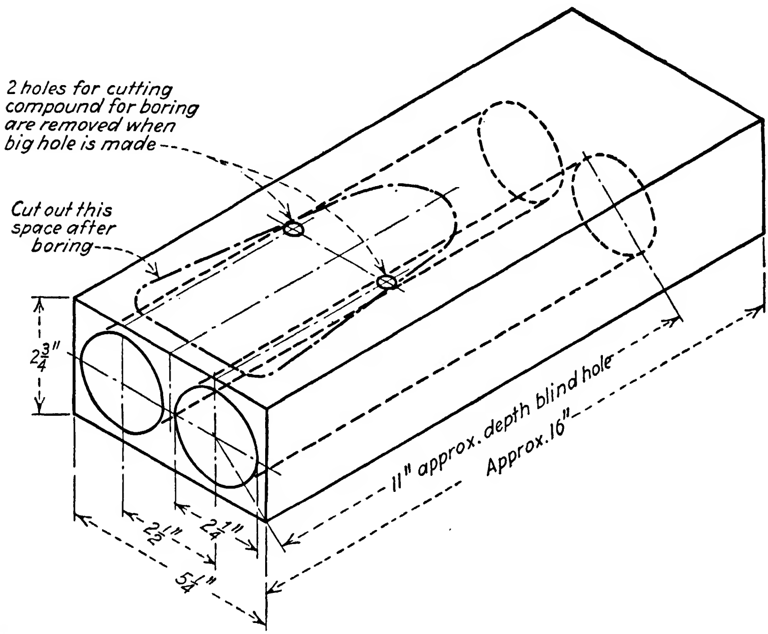


FIG. 59.—This job presented no growth or warpage complications, but chips caught between the coolant holes and the tool edges and spoiled the main holes.

have the outer parts cut away like the first. It is tied together quite well and presents no warpage or growth complications. It is also shown for another reason mentioned later.

Top Rake.—In turning, top rakes of tools should be between 30 and 45 deg., the latter for 17ST, the former for the high-silicon alloy. When satisfactory top rake is ground on ordinary tool bits, they are somewhat weakened, particularly since they are loaded in clamping. The wedge-locked tool holder, Fig. 60, has the advantage that the tool clearance is fixed, top rake is easily controlled and bending load on the tool bit is minor. A smart rap on the underside or end of the bit loosens it for resharpening

by grinding the top surface. The shank is of medium-carbon alloy steel, hardened and drawn to about 330 Brinell, the holes being put in after heat treatment, which is still possible, though a trifle slow. The wedge is harder. Serrations in the tool are coined in the annealed stock. The serrations make such a tool

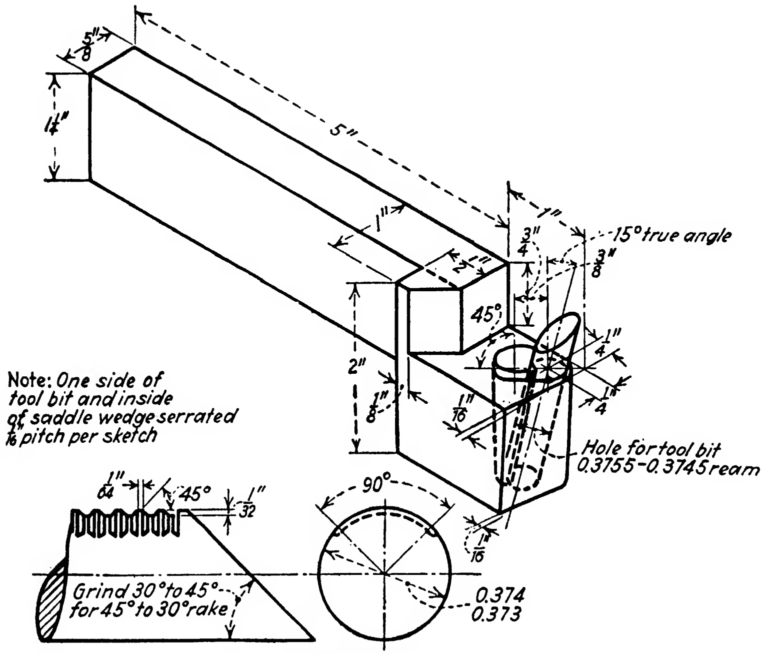


Fig. 60.—Serrations in this wedge-lock tool holder permit heavy and intermittent cutting, and besides the tool bit is not weak as is an ordinary bit ground for aluminum.

suitable for heavy and intermittent cutting. Figure 61 shows an adaptation of Fig. 60 made by substituting a hollow setscrew for the wedge. The tool bit may be twisted to different positions with respect to the shank, but unless the bit is backed up by a bottom stop it is not good for intermittent cutting.

Holders made right- or left-handed are satisfactory for shaper work. Figure 62 shows a tool used for obtaining reasonably good finish at one cut, removing about 1/16 in. of material at 3/32 in. fed per stroke. Such a bit is held in Armstrong planer-type tool holders, and the edges are stoned after grinding on the cutter grinder.

Milling Clearance.—In milling, the peripheral clearance should be 7 deg., which is greater than for steel. Ordinary cutters are

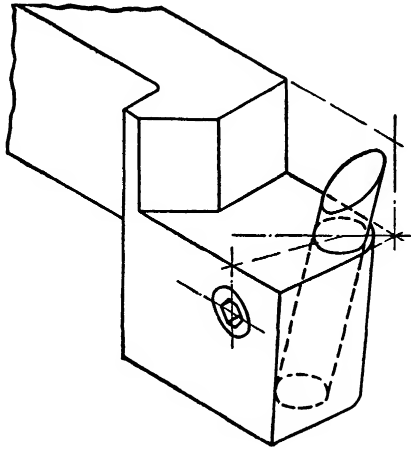


FIG. 61.—Cheaper construction than Fig. 60, but not good for intermittent cuts unless backed up with a stop such as a setscrew.

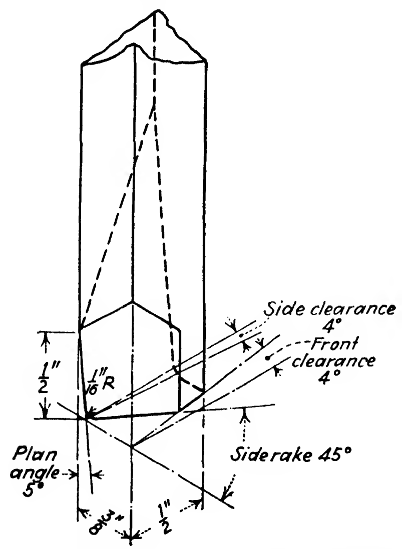


FIG. 62.—Shaper tool for use in planer-type tool holder.

deficient in rake, and if ground for light alloys are quickly dulled when used on other materials. Figure 63 shows a suitable face-mill design, with teeth pressed into the machine-steel body.

When making cheap tools, there is no necessity to use any other locking means than the press fit. Relatively large chip room is necessary, however, hence the coarse pitch of the teeth.

Figure 64 shows the tool-bit end of the final drill used for boring the 2¼-in. holes of the part shown in Fig. 59. When enlarging the hole from 2 or even 2⅛ in. the chips did not clear.

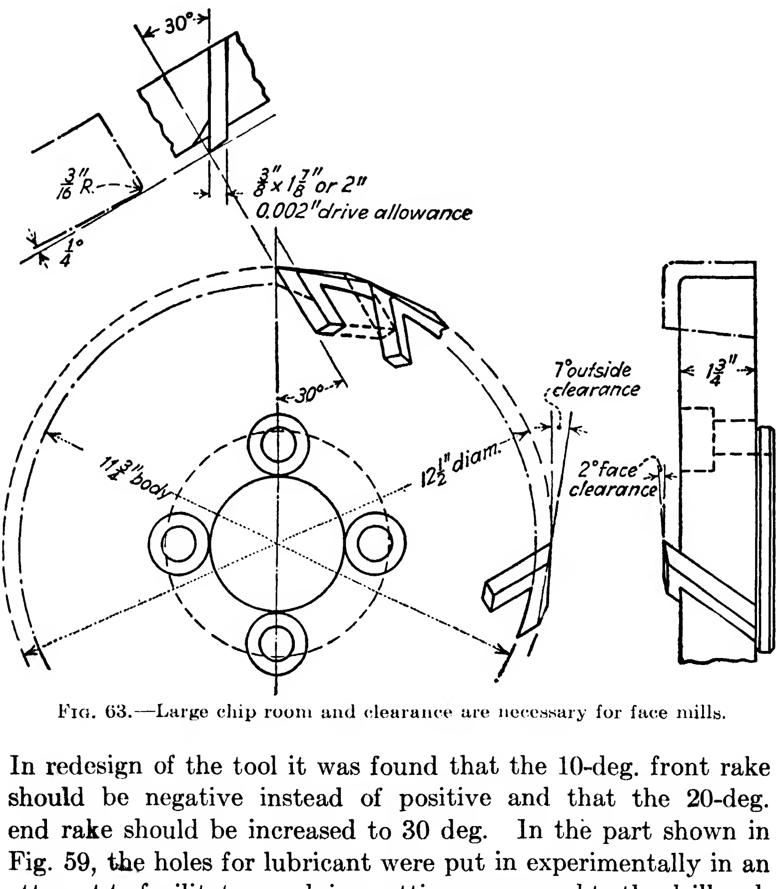


FIG. 63.—Large chip room and clearance are necessary for face mills.

In redesign of the tool it was found that the 10-deg. front rake should be negative instead of positive and that the 20-deg. end rake should be increased to 30 deg. In the part shown in Fig. 59, the holes for lubricant were put in experimentally in an attempt to facilitate supplying cutting compound to the drill end. Actually they were a hazard, chips catching in them caused scratches in the bores.

Figure 65 shows a counterbore, or stub-boring tool, made from a scrap twist-drill stub. This is split up the web with a 3/16-in. abrasive cut-off wheel, forged to shape, rehardened, and ground.

It definitely meets requirements of rake, clearance, and chip room.

Reaming and Tapping.—Certain precautions are necessary when performing reaming and tapping operations on the light alloys. *It is essential that the faces of the cutting edges be ground and stoned.* Figure 66 shows the cutter used for finishing triple-cylinder castings having blind holes about 10½-in. deep, the material being 194HT 4 casting alloy. Total material removed was ⅛-in. per side. Kerosene, supplied through ⅜-in.-

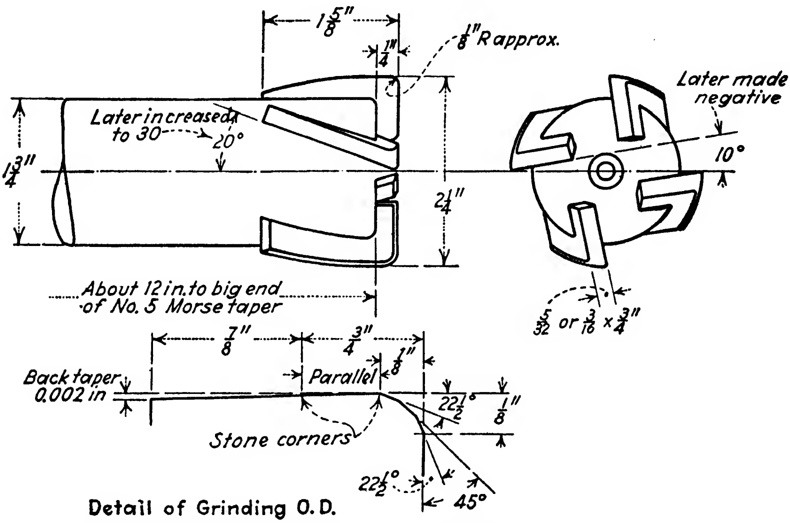


FIG. 64.—The main holes, Fig. 59, were brought to size with this tool. Modifications should be made as described in the text.

pipe tap holes in the closed end, acted as coolant and washed out the chips. Final boring or reaming of such a job must be carefully done because of expansion effects; that is, the hole closes down on the reamer after it has entered. Unless lots of cool compound floods the work, withdrawal of the reamer leaves scratches deep enough to demand a re-reaming job. However, when preceded by a single-point tool and with the above precaution taken, these tools gave very satisfactory results on a 3-in.-bar boring machine. When first made, the twist of the blades was left-hand for the finisher, but, although only 0.004 in. per side was removed, the surface finish was not satisfactory.

A refinement in cutting straight-flute taper reamers, with

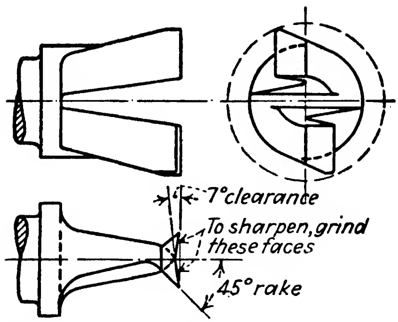


Fig. 65.—A counterbore or stub-boring tool can be made from a scrap twist-drill stub.

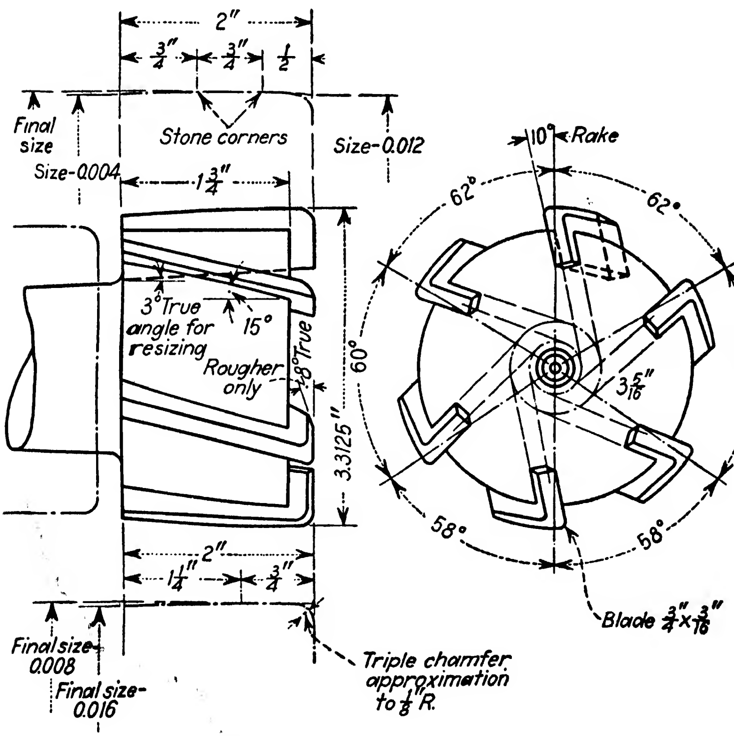


Fig. 66.—Roughing and finishing reamers used for $3\frac{5}{16}$- by $10\frac{1}{2}$-in. cylinder bores, material 194HT 4 casting alloy. Copious coolant was necessary to prevent the hole closing on the reamer because of expansion from heat.

either radial or raked teeth, is illustrated in Fig. 67. When using standard fluting cutters, it is necessary to have the cutting edge lie in the axial plane. The offsets are not the same at the large and small ends of the reamer, so it has been the practice to

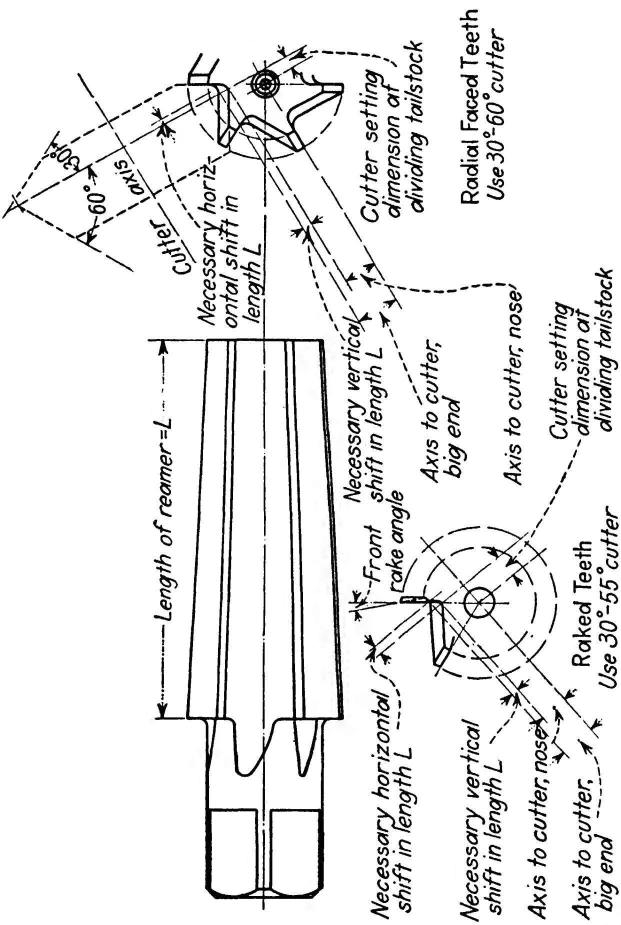


Fig. 67.—Horizontal and vertical inclination of the work are both necessary when fluting straight-toothed taper reamers.

specify both settings. The dividing head and tailstock are set on an auxiliary bar to get the horizontal shift. The milling machine settings may be made directly from the drawing and the reamers cut directly without "cut and try" time losses.

In making helical-fluted finishing reamers, the dividing head must be parallel to the milling machine table, and horizontal

compensation cannot be had. Consequently, the offset is made for average conditions (Fig. 68). Because of interference between the cutter and work, causing the face of the tooth to tend toward negative rake, special reamers of this type should not be milled with 30 to 36-deg. fluting cutters. The 30 to 55-deg. or 30 to 50-deg. cutters have been found more suitable. The offset should be such as to give initially more rake than specified. Since the rake varies with the depth of cut, there

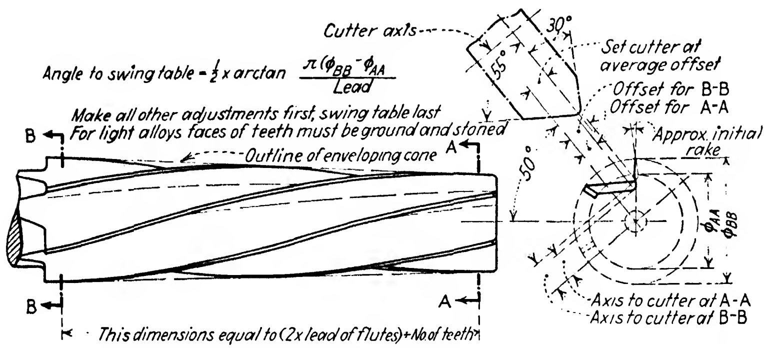


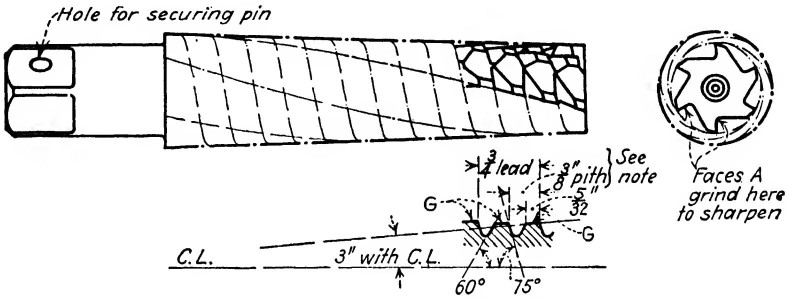
FIG. 68.—Offset is made for average conditions when milling helical-fluted taper-finishing reamers in one cut.

seems to be no easy way out other than a check set-up with a soft duplicate blank. The table is swung to only one half the usual helix angle, and the rake is adjusted by the change of this angle. Maximum flute lead is equal to the axial length of the flute minus ¼ in. multiplied by one half the number of teeth, and it permits checking the finished taper by the twin straight-edge method.

An integral series counterbore as a substitute for the usual notched roughing taper reamer is illustrated in Fig. 69. This tool removes stock rapidly. Clearance and rake are obtained by choice of hands of the two families of grooves and their leads. The two surfaces ground are the taper of the threads, with 3 deg. back taper, and the faces of the gashes, the taper of the threads being ground in the lathe, and the faces of the gashes in the cutter grinder. The transverse gash section is not critical since the tool is end-cutting. Feeding pressures are low, sometimes negative, hence provision of the cross pinhole in the shank.

Tapping.—Tapping aluminum alloys presents trouble, particularly where oversize pitch diameter holes must be avoided.

Ordinary taps ground to Bath 01 tolerances have been found to cut just over the high limit for Class 3 threads. Commercially ground taps were entirely unsuitable. They are a good general-purpose tool and satisfactory for many uses, but tapping close-tolerance holes in aluminum alloys has not proved to be one of them. Taps for aluminum alloys should be kept separate from other taps and should be machine-ground when necessary, either in the face of the flute or on the outside, or both.



Note: *Chase (see section drawing) double-thread, right-hand, leaving stock at G. Choose lead so that helix angle is 78 to 82 deg. Mill right-hand flutes Choose lead so that helix angle is 15 to 18 deg. Harden and grind screw surface to 3 deg back taper with C.L. in lathe Relief or clearance exists because of screw surface relationships Grind no clearances in cutter grinder to sharpen grind faces A*

FIG. 69.—Roughing taper reamer or integral series counterbore that is a good stock remover.

It is not generally recognized that during the start of tapping a hole, the tap itself is subjected to a stress tending to tilt it, even though it may be geometrically perfect in accordance with its designed shape. The magnitude of the stress is somewhat proportional to the pitch of the thread and to the steepness of the nose taper. It has zero value when the number of flutes is a multiple of the number of "starts" on the tap (when these are greater than one). With such symmetry a tap has a chance to start and enter straight. However, the single-thread tap does not meet this specification.

Tap Grinding.—Free-hand grinding of tap noses results in bell-mouthed and oversize holes which easily exceed the small tolerances permitted in Class 3 threads. A change of specification from Class 3 to Class 2, wherever possible, is a distinct help in producing acceptable work. The small increase in tolerance brings about a much larger increase in accuracy. Another

means of avoiding oversize holes is as follows: A steel plate is threaded to fit the tap and is then clamped on the work to align with the hole, the tap is entered, and the hole tapped.

The best tap so far found for this work is illustrated in Fig. 70. In sizes up to ½ in., two flutes are satisfactory, the tap being ground all over. The front and side rake make for face cutting, the chips curl up out of the hole like drill chips, and the power

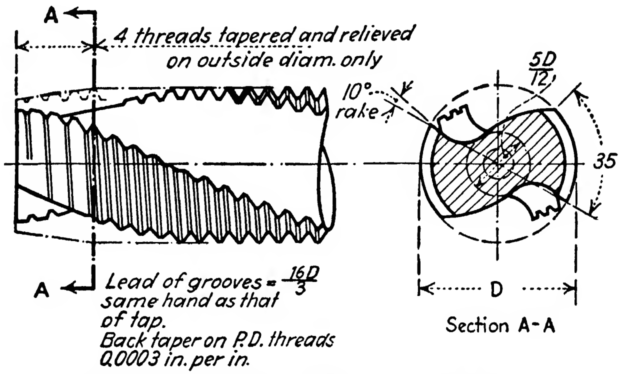


FIG. 70.—Close tolerance tapping is best done with a helical-fluted tap.

consumption is small. Taps from ⅜ in. to No. 24 S.A.E. have cut repeatedly within 0.006 in., of their own pitch diameter in dural. The Aluminum Company of America has suggested making taps out of old twist drills as an emergency measure, but such taps as that illustrated are now commercially available, although at some advance in price.

Sometimes tank parts made of 2 S wrought aluminum have to be threaded, and because of the high elongation properties of the material are often chased in the lathe. Use of the helical flute tap, Fig. 70, or of the old "Echols" interrupted-thread tap, developed years ago for tapping staybolt holes in copper firebox plates, is strongly to be urged, particularly when tapping tapered pipe thread holes. These holes should be taper reamed before threading.

CHAPTER XXII

SUGGESTIONS FOR MACHINING VARIOUS METALS

Drilling of Alleghany Metal.—The manufacturers of Alleghany metal, which is a stainless steel of the 18-8 chromium-nickel type, have made the following recommendations for the drilling of this material:

A high-speed drill should be used for this material, with the point ground somewhat flatter than the standard. Layouts should be made with a triangular-nosed center-punch, taking care not to make the mark deeper than necessary, in order to avoid work-hardening and thus making it difficult to start the drill. On account of the work-hardening characteristics of Alleghany metal, it is necessary to exert sufficient pressure on the drill to make it cut all the time.

It is very important that this metal be properly backed up, because it does not chip or break out ahead of the cutting point of the drill, as does ordinary steel, and the drilling must be done all the way through. The speed of the drill should be about one half that used for mild steel. Immersing the drill in water after each hole is drilled will prolong its life considerably.

The low-speed electric hand drills recently brought out by several manufacturers are much better for drilling this metal than the older types, in which the speeds were too high. The drill must be kept cutting when in contact with the work to prevent work-hardening. In drilling deep holes, a compound of 1 lb. of sulphur to 1 gal. of lard oil will prove advantageous.

Machining of Aluminum.—Milling cutters work to best advantage in machining aluminum and its alloys if they are of the coarse-tooth helical type and have a considerable amount of top rake on their cutting edges. In some instances milling cutters with nicked teeth assist in decreasing the chip size. Face milling cutters with inserted teeth should be designed so that the inserted teeth have appreciable top and side rake. The comparatively new helical milling cutters, primarily designed for machining steel, work especially well with aluminum and its

alloys if the cutting edges are provided with suitable top rake. The same may be said of staggered tooth milling cutters.

Ordinary twist drills sometimes give trouble when machining aluminum and its alloys. Like all other cutting tools for aluminum, twist drills should have keen edges, and a copious amount of cutting compound should be used with them. In some instances the single-fluted twist drills used in drilling hard wood have been found superior to the usual form of drill. A still better drill for aluminum is one in which the flutes have a greater helix angle.

Reamers of the helical-fluted type produce by far the best results when machining aluminum and its alloys.

Saws for cutting aluminum should have comparatively coarse teeth with curved gullets free from sharp corners and burred edges to eliminate danger of chips sticking.

Aluminum can be machined to best advantage by using comparatively high speeds and fine to medium feeds.

To get the best results some form of cutting lubricant is quite desirable. For many purposes a soluble cutting oil is good. A satisfactory mixture for general use will be obtained by using equal parts of kerosene and lard oil.

These instructions are in line with the recommendations of the largest manufacturer of aluminum products.

MAGNESIUM BASE ALLOYS (DOWMETAL)

In recent years there has been developed a series of magnesium base alloys (better known as Dowmetal), which, because of their extreme lightness and comparatively high structural strength, are finding a constantly widening field of application.

Generally speaking, the machineability of these alloys is very good, so that high cutting speeds and heavy feeds can be used without danger of burning the tools. Speeds in the range from 500 to 1,200 surface feet per minute can be used, depending on the depth of cut and on the feed. Permissible feeds are limited only by the quality of finished surface desired.

It is very important that cutting tools are kept sharp and that they have sufficient clearance. Sharpening should be done with a fine grit wheel so that a keen, smooth cutting edge is produced. Care must be taken to see that there is no land behind the cutting edge. Such tools as slotting cutters or saws should have more than the conventional amount of concave or side clearance.

The following suggestions regarding Dowmetal is given by the manufacturers:

Machining.—A fine smooth finish is readily secured with no tendency to drag, tear, or chip out. Heavy cuts and feeds may be taken at high speeds without excessive heating of cutting tools or work. Experience in the average machine shop has proved that practically all machine tools can be run at their maximum speeds with feeds to the full capacity of the machine. Machines using tungsten carbide cutting tools are ideal for the production of Dowmetal parts, using high-speed-steel cutting tools. Cuts as heavy as ½ in. with feeds of 20 in. per minute and speeds of 700 ft. per minute are being used for turning Dowmetal. Light finishing cuts have been made at speeds of 1,400 ft. per minute.

TABLE XXV.—RELATIVE MACHINEABILITY OF METALS
(Horsepower per Cubic Inch of Metal Removed per Minute)

Material	Operation		
	Planing	Drilling	Milling
Dowmetal	1.00	1.00	1.00
Bearing bronze (70Cu-25Pb-5Sn)	1.51	1.20	1.36
No. 12 aluminum alloy	2.21	1.69	1.57
No. 31 aluminum alloy	2.58	2.21	1.56
Yellow brass (70Cu-27Zn-2Pb-1Sn)	2.22	2.02	2.58
Brass screw stock	2.26	1.76	2.10
Cast iron	4.08	3.41	3.05
S.A.E. 1112	5.89	4.91	6.13
Steel screw stock	7.03	5.45	5.36
S.A.E. 1020	6.88	6.50	5.83
Copper annealed	7.49	10.00	5.49
Nickel "A"	12.53	13.00	9.06
Monel metal	13.32	8.20	8.72

Less power is required to machine Dowmetal than to machine other metals, as is shown in Table XXV, calculated from the work of Prof. O. W. Boston. Thus, it is possible to take advantage of the easy machineability of Dowmetal to increase production, and at the same time have an actual reduction in operating and maintenance cost of the machine equipment.

Cutting Tools.—In order to secure the best results in machining Dowmetal, the proper procedure and cutting tools must be

employed. While carbon-steel cutting tools can be successfully used, high-speed-steel cutting tools are recommended, particularly on accurate production operations. It is very important to keep the cutting tools sharp, using a fine-grained abrasive wheel and finishing the edge by hand-honing to remove all burrs and wire edges.

Cutting tools previously used on other metals should not be used on Dowmetal. This applies particularly to drills, reamers, milling cutters, slitting saws, broaches, dies, taps, etc., where there is a strong possibility that the clearance has been reduced through wear. Often the difference between a cutting tool giving satisfactory service and one which does not is hardly noticeable to the eye. Cutting tools to be used on Dowmetal should be freshly ground with special care that *the clearance runs up to the cutting edge.* Excessive heating of the work, failure of the tool to cut properly, a rough surface, and squeaking or laboring of the tool, are all indications that the tool should be checked immediately for sharpness and clearance.

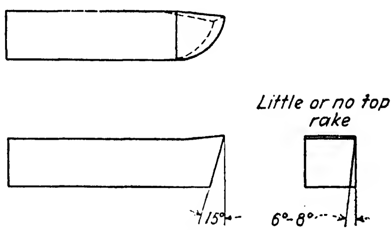


FIG. 71.

Turning, Shaping, and Planing.—These operations require a tool form similar to that for brass, approximately as indicated in Fig. 71.

Parting.—Parting tools should have a minimum side clearance of 6 deg., with little or no top rake, and an included tool angle of 75 deg. Tool breakage is rare if these suggestions are followed.

Milling.—Coarse-tooth milling cutters of the helical type are recommended. They should be ground without land. The relief behind the cutting edge should be about 6 deg.

Drilling.—Ordinary twist drills, when ground to standard shape, operate satisfactorily in Dowmetal. Polished or chrome-plated flutes help in discharging the chips.

Reaming.—Reaming should be done with left-hand helical reamers, ground without land. There should be about 6 of relief behind the cutting edge.

Threading.—Dowmetal is easily threaded in the lathe or with taps and dies. Standard four-fluted taps are most satisfactory. Special attention is called to the necessity of using sharp tools

to secure clean threads on production work. Drilled holes for tapping should be slightly larger than root diameter of thread.

U. S. S. threads are generally recommended, but greater strength will be secured with S. A. E. threads. Studs with U. S. S. threads should be screwed into Dowmetal a distance equal to twice the diameter of the stud, and with S. A. E. threads a distance of two and one half to three times the diameter of the stud. No difficulty is experienced with threaded joints seizing, either with both parts Dowmetal or between Dowmetal and other metals. Roll-threading of Dowmetal is not satisfactory, as it involves excessive cold working of the metal.

Sawing.—Dowmetal is easily cut on ordinary band saws, using spring-temper metal-cutting saws of 20-gage thickness with four teeth per inch. A finer pitch does not give sufficient clearance between the teeth. The set should be somewhat greater than is customary in this type of saw. Lubrication with a tallow stick will improve the performance of the band saws. The cutting speed should be about 4,000 ft. per minute.

Hand hacksaw blades should have 14 teeth per inch. Power saws operate satisfactorily with 10 teeth per inch and may be run at the highest speed without burning of the teeth. Sharp saws must be used to secure good results.

Metal-slitting saws should be coarse-pitched (3/8 in.) and should have at least 6 deg. relief or side clearance.

Filing.—Single-cut files are best for Dowmetal. The type known as "body workers' " files are quite satisfactory for heavy work. Files should not be used on other metal prior to using on Dowmetal.

Grinding.—Medium-hard wheels (K to M for alundum or L to P for crystolon) with a grain size of 30 to 46 are recommended. A grain size of approximately 20 is recommended for snagging in foundry clean-up work. Wheels used for Dowmetal should not be used for grinding steel, or other ferrous metals, as the sparks may ignite the Dowmetal dust.

Wheels treated with wax during their manufacture are recommended and are used dry with no lubricant. Lubrication with oil or a 3 to 4 per cent soluble oil solution may be desirable to prevent clogging in case of fine grinding on untreated wheels. Grinding dust should be disposed of as indicated under Fire Hazard and Prevention.

Cutting Lubricants.—Owing to the easy machineability of Dowmetal and the slight generation of heat in ordinary machining operations, the use of a lubricant or cutting compound is generally unnecessary. From the scrap standpoint, it is desirable not to use a lubricant, since the value of Dowmetal shavings is greatly reduced when contaminated with oil and water. In certain very high speed operations, however, such as screw-machine work where relatively fine shavings are produced, the use of a coolant is recommended to reduce the fire hazard and to give the smoothest finish to the work. Kerosene, kerosene and lard oil mixtures, or soluble oil solutions can be used for this purpose.

Fire Hazard and Prevention.—While there is no record of any serious fire occurring through the machining of Dowmetal, the fire hazard should not be overlooked. This hazard is very slight and no trouble is experienced when operators understand the situation and take the simple precautions which are necessary. Dowmetal must be heated to near its melting point before it will ignite. On heavy roughing cuts where coarse shavings are produced, there is but slight danger from fire. A hazard does exist, however, as higher finishing speeds are used with the production of fine light shavings. Fires are started by friction at the cutting edge of the tool. It is because of this fact that emphasis has been placed upon the maintenance of sharp tools, ground with adequate relief or clearance, to secure a true cutting action with as little friction as possible, and upon the use of a lubricant or cooling medium in very high speed work.

In ordinary work, such as on an engine lathe, the material is generally machined dry. Fine shavings or dust should be brushed off the machine frequently as it is here that fires are most likely to occur. Shavings should not be allowed to accumulate under machines, but should be cleaned up periodically and stored in covered metal containers. Suction systems can be used for handling dry turnings. The equipment should be so arranged that there are no pockets in which turnings can collect before reaching the separator. On high-speed automatic machines where quantities of fine light shavings are produced, there will be no hazard if a coolant is used in sufficient volume.

Fires in Dowmetal shavings are best extinguished by the use of a blanket of dry, noncombustible, fine-divided or powdered material such as graphite, salt, cement, sand, or earth (listed

in order of their merit). Graphite has an added advantage for use with fires on machine tools in that it is nonabrasive and noncorrosive. Always apply the materials gently to avoid scattering the fire. Liquid extinguishers such as water, Pyrene, Fire-Foam, etc., should not be used because of their tendency to scatter the fire.

If operators will observe these few precautions, serious danger from fires will be eliminated:

1. Keep cutting tools sharp and, if possible, use only for Dowmetal.
2. Keep machines and floor clean.
3. Keep scrap in covered metal containers.
4. Use a coolant on high speed automatic operations.
5. Do not grind sparking material near accumulations of Dowmetal shavings or dust.
6. Use dry fire extinguishers only—never water or other liquids.

The machining of Dowmetal presents no production problem or unusual hazard which cannot be readily solved by good shop management with the assistance of trustworthy and intelligent operators.

MACHINING DURALUMIN

Tests by Prof. John Younger and W. R. Jenkinson of Ohio State University on duralumin of 55,000 to 63,000 lb. tensile strength and a Brinell of 90 to 105 with 500-kg. load and a 10-mm. ball show interesting results with speeds of from 86 to 700 ft. per minute with cutters of 4, 6, and 8½ in. The helix angles of the teeth included 15 and 45 deg. Coarse-toothed cutters give best result as they avoid clogging of the chips in the teeth. An interesting factor is the power required for different rates of feed. With the standard cut taken, the power required increased much more slowly than the rate of feed. Starting at 4 in. per minute as the minimum, we find that 8 in. per minute takes but 25 per cent more power and 20 in. per minute, or five times as fast, takes but little more than double the power of the 4-in. feed.

Kerosene was found to be a very good coolant in all the tests made.

MACHINING HY-TEN-SL BRONZE

Bronzes of high strength can be machined without difficulty if care is given the tools used and the way in which they are set.

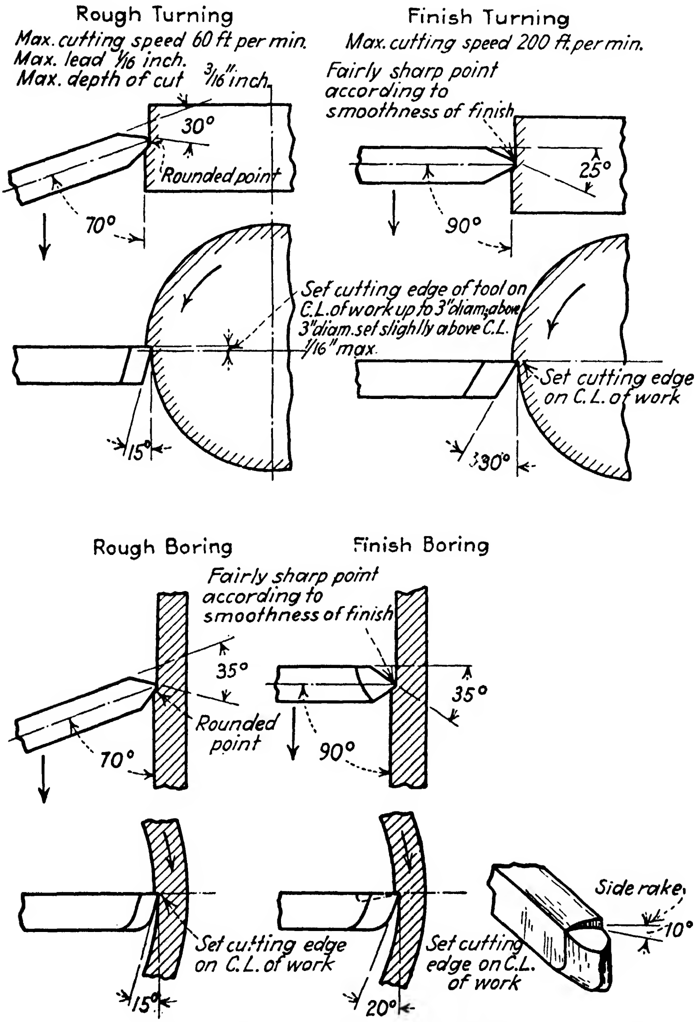


Fig. 72.—Recommended cutting angles for machining Hy-ten-sl.

Much, of course, depends on the mixture of the metal used, but the tools recommended by the makers of the alloy known as Hy-ten-sl bronze will aid in machining other bronzes of a similar

nature. The diagrams (Fig. 72) show the tools suggested for rough- and finish-turning and boring. They also show how the tools should be set for best results and the shape of a tool that has been found satisfactory. For rough turning a deep cut and a light feed, with a maximum roughing speed of 60 ft. per minute, are used, while for finishing cuts 200 ft. per minute is permissible. The metal in question has a Brinell hardness of from 150 to 245, according to the grade.

MACHINING MONEL METAL

Turning.—Sharp cutting angles are necessary on lathe tools and are obtained by grinding them with either large top rake or

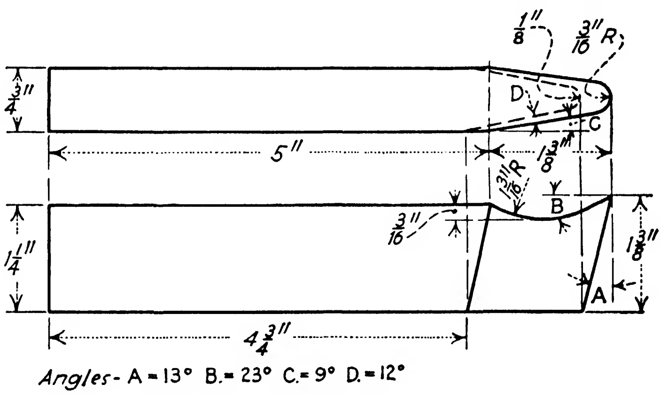


FIG. 73.—Turning tool for monel metal.

combined top rake and side slope. One good design is shown in Fig. 73. An alternate tool has a 6-deg. clearance angle and a combined 8-deg. side rake and 14-deg. side slope. Both tools cut cleanly and rid themselves easily of the long tough chip. High-speed steel is recommended for lathe tools and should be tempered to give a tough rather than a hard cutting surface. Satisfactory heat treatment is as follows: heat slowly to 1,800°F., then rapidly to 2,200°F., quench in fish oil and draw at 1,000°F., followed by slow cooling in a closed box.

Threading.—Lathe tools for threading are ground with smaller top rake and clearance angles of 9 and 12 deg., respectively, to offset the greater tendency to crumble. The sides of the nose are ground on a gentle slope from the top to the bottom. The clearance angle for ⅜- and ⅝-in. tool bits should be made large

enough to avoid rubbing the flank of the tool against the work. Top rake is not necessary for a 3/8-in. tool bit, but a 4-deg. side slope is advantageous for a 5/8-in. tool bit. For small work tools with nose offset are desired. Tools should be honed after grinding. Cast monel metal has a tough outer skin, so a tool with a blunter edge stands up better although it does not cut so cleanly.

Drilling.—Carbon-steel and high-speed steel drills of the standard twist-drill design can be used. Carbon-steel drills stand up better by using a cutting speed of 20 to 30 ft. per minute with 0.005 in. feed. High-speed steel drills perform well at a cutting speed of 50 ft. per minute with 0.003 in. feed. Good results can also be obtained from high-speed steel drills with 28 to 32 deg. helix angle, regular point and with extra back taper to eliminate gumming. These drills will operate at a cutting speed of 40 to 60 ft. per minute and heavier feed than usual with steel.

Table XXVI.—Feeds and Speeds for Regular Monel Metal

Cut, in.	Feed, in.	Cutting speed, ft. per min.	
		Cast	Rolled
1/64	1/64	150	170
1/64	1/32	120	140
1/32	1/64	100	115
1/32	1/32	90	100
1/32	1/16	75	85
1/16	1/64	85	95
1/16	1/32	70	80
1/16	1/16	50	55
1/8	1/64	75	85
1/8	1/32	60	70
1/8	1/16	45	50
1/8	1/8	40	45
1/4	1/32	50	55
1/4	1/16	40	45
1/4	1/8	30	35

Reaming.—Helical-flute reamers of high-speed steel are preferable for this operation. Cutting speed should be 10 to 15 ft. per minute and a slow feed should be used to prevent tearing the metal and wedging it in the flutes.

TABLE XXVII.—RECOMMENDED SPEEDS AND FEEDS FOR AUTOMATIC SCREW MACHINING OF "SPECIAL MACHINING QUALITY" MONEL METAL ROD

Operation	Width of cut, in.	Feed	Speed, ft. per min.
Box tool			
Roughing	1/32	0.006	125
	1/16	0.005	125
	1/8	0.004	125
Finish	0.005	0.010	125
Cut-off			
Circular	3/64 to 1/8	0.001	125
Straight	1/16 to 1/8	0.001	125
Stock under 1/8 in. diameter	....	0.0005	125
Twist drills			
	1/16	0.002	60
	3/32	0.0025	60
	1/8	0.003	60
	3/16	0.0035	60
	1/4	0.004	60
	5/16	0.0045	60
	3/8	0.005	60
	1/2	0.005	60
	5/8	0.005	60
	1	0.013	
Forming tool			
Circular	1/8–1/4	0.0006	125
	3/8–1/2	0.0005	125
	5/8–3/4	0.0004	125
	1	0.00025	125
Balance turning tool			
Turned diameter			
Under 3/32 in.	1/32	0.006	125
	1/16	0.005	125
Over 3/32 in.	1/32	0.012	125
	1/16	0.010	125
Tabs	H. S. S.	....	30–40
Dies	Self-opening Die head	....	40–50

Tapping.—Shallow flutes and two or three lands are required on taps for monel metal. The lips should be ground back of

the cutting edges to curl the chip through the flutes. When tapping completely through, grind the cutting edge at a 10- to 15-deg. angle to the axis and with a chamfer for four or five threads. Gun taps are satisfactory for this material. The best general cutting speed is from 15 to 20 ft. per minute.

Milling.—Sharp cutting angles and high-speed cutters are required. For plain milling cutters the teeth should be ground at a slight taper, widest at the cutting edge, to prevent binding and tearing. Undercut or rake on the teeth is beneficial. Average cutting speed is from 70 to 80 ft. per minute with 1/8 in. cut and 0.005 to 0.01 in. feed per revolution, although the depth and the surface speed depend on the strength of the machine. It is advantageous to use tools with increased rake angle.

Tables XXVI and XXVII give data regarding monel metal.

MACHINING OF NICKEL CHROMIUM ALLOYS. (INCONEL)

An alloy of nickel and chromium has been developed for use under conditions where a material is required that will combine good working properties and strength with high resistance to corrosion. The composition of an alloy well suited for this purpose is approximately 80 per cent nickel, 14 per cent chromium, and 6 per cent iron.

The tensile strength of this alloy will vary from 80 to 95,000 lb. per square inch for the annealed material, to 175 to 200,000 lb. for tempered wire. The elongation of the annealed material is 45 to 55 per cent with a 65 to 75 per cent reduction in area.

The material is not only highly resistant to corrosion, but it is also free from staining and tarnishing. These properties have made the material particularly useful for such applications as food-handling containers and machinery.

The following recommendations for machining may serve as a guide:

Drilling.—Use regular types of twist drills. Speed 35 to 45 surface feet per minute. Regular feeds can be used. Sharpen with an included angle of 135 deg. Keep drills sharp.

Reaming.—Helical-fluted reamers are recommended. Speeds about 15 ft. Feeds about twice those used for drilling. Reamers must be kept sharp for best results.

Milling.—The regular types of milling cutters are satisfactory. Speeds not in excess of 40 ft. except on very light cuts. Feeds

from 0.003 to 0.006 per tooth depending on the depth of cut. Sharpen cutters carefully and often.

Lubrication and Cooling.—This material does not pick up on the tool to any great extent, but a cutting fluid should be used in all cases. A sulphur base oil is found most satisfactory.

MACHINING OF NITRIDED STEELS

Definite classes of steels are being produced and marketed for parts that are to be nitrided after finishing. These are commonly referred as "nitralloys."

The nitriding process consists of treating parts made from these materials with ammonia gas at comparatively low temperatures (usually 700° to 1,000°F.) This treatment produces an extremely hard surface on the parts treated, the depth of the hardened surface depending on the length of the treatment.

Nitriding steels differ from other alloy steels principally in that they contain about 1 per cent aluminum. The general analysis is:

Carbon	0.15 to 0.35
Manganese	0.50
Aluminum	1.00
Chromium	1.25
Molybdenum	0.20

The machining properties of nitralloy steels do not differ from corresponding alloy steels not containing aluminum. Drilling, milling, and turning can be carried on at speeds and feeds used on chromium-molybdenum steels. Speeds should be kept in the 45- to 65-surface-feet range for the ordinary feeds.

It should be noted that nitralloy steels are capable of being hardened or toughened by ordinary types of heat treatments. This is often done to produce a stronger core in the piece. If machining is done after such heat treatments, this must be taken into account, with feeds and speeds adjusted to suit the hardness or toughness of the piece at the time of machining.

In general, nitralloy steels present no difficult machining problems, nor do they require any special types of tools, except where other conditions may make such tools necessary.

QUALITY OF FINISH OF MACHINED SURFACES

Machined metal surfaces are usually subject to inspection for quality of finish. They must meet certain requirements, depend-

ing on the purpose for which the parts or surfaces are to be used. In general, the permissible roughness of a finished surface is determined by the accuracy of dimensions required and by the desired contact area with some other surface. In some cases, too, the appearance of an exposed surface may have a bearing on the quality of finish that must be produced.

Real or Apparent Finish.—A casual inspection of a machined surface may sometimes be misleading as far as finish is concerned. The real measure of a good finish is that all points of the surface lie in the same plane if the surface is flat, or in the same cylindrical plane, if the surface is rounded. Now, if the cutting tool has rubbed the surface so that it is glossy, it may appear to have a good finish, even though in reality it is very rough. On the other hand, we may have a surface that has been cut with a keen edge that appears rough because it has not been rubbed, but which in reality may have a fairly good finish.

The University of Michigan uses an apparatus that is capable of making a graphical record of the actual finish of a machined surface. With this apparatus exact measurements of roughness can be obtained.

Causes of Poor Finish.—There are several factors that contribute to the roughness of finished surfaces. The nature and structure of the material to be machined will affect its finish. For instance, it is nearly always difficult to give a good finish to steels that are very soft. The reason is that the structure of these soft steels usually is of a laminar nature (made up of layers). These layers tend to tear apart at irregular points, thus producing a rough surface. Steels that are somewhat harder, but have a spheroidal structure, can be given better finishes because they are cut apart rather than torn.

Dullness of cutting edges will, invariably, cause rough surfaces. This is especially true if the edges are nicked. Any irregularity of the cutting edges will be reproduced on the finished surface.

Excessive widths of lands behind the cutting edges will cause rubbing. If enough heat is generated by this rubbing, the material will be softened and begin to tear. Lack of rigidity in the machine, the work or the tool will cause roughness through chatter.

Run-out of the tool, arbor, or tool spindle will also cause roughness. This is a different type of roughness, commonly

spoken of as "revolution marks," and is usually found on milled surfaces. The surface presents a wavy appearance, one for each revolution of the cutter. The amount of roughness of such surfaces is often more apparent than real owing to the reflection of light.

Absence of cutting lubricants, or the use of poor ones, may also be a cause of rough finishes. If the cutting medium does not have sufficient cooling and lubricating qualities, there is a tendency of the chips to stick to the cutting edges, and to be carried into the cut itself, thus scoring the surface.

Remedies for Poor Finishes.—When rough-machined surfaces are encountered, a study should be made of the various factors influencing the finish, and provisions made to correct or eliminate the undesirable ones.

A slight change in steel structure or hardness sometimes will made a great difference not only in the quality of finish obtained, but also in the permissible feeds and speeds.

Proper and timely sharpening of tools is perhaps one of the most important items, as this affects both the finish obtainable and the overall life of the tools. It is always poor economy to overdull any tool.

Stiffening of the machine, the fixtures, and general setup to eliminate chatter is such an obvious matter that it hardly needs to be mentioned here.

Run-out of the tools, particularly of milling cutters, can be readily corrected, first by proper sharpening, and second by proper mounting in the machine. Both are important and should be watched carefully.

Cutting lubricants should possess cooling and lubricating qualities of the highest possible order. In this same connection it should be noted that the chips must be carried away from the cut as they are made so as not to be dragged back into the cut and cause roughness.

CHAPTER XXIII

MACHINING NONMETALLIC MATERIALS

Tungsten carbide tools are preferred for machining Formica, Micarta, Textolite and other similar materials because these materials are abrasive. High-speed steel tools are frequently used for small-quantity work, but carbon-steel tools are not employed. Diamond tools are rarely used. Coolant is seldom applied, but an air blast has some cooling effect for drilling operations and is useful in removing chips and dust in this and other operations.

FORMICA

Formica is a laminated gear material made by the Formica Insulation Company, Cincinnati, Ohio. The material is made of cotton duck impregnated with a phenolic resin.

Turning.—The outside diameter and sides of gear blanks are turned with the tools illustrated in Fig. 74. Such tools must have 3 to 5 deg. more rake and clearance than is common for metal-turning tools. Speeds up to 750 ft. per minute can be used successfully. Cut can be from 1/16 to 1/8 in., but the feed should be 0.030 in. regardless of the cut. The cut should overlap the feed. Provision should be made in grinding the tools so that they clear themselves.

Threading.—Chasing tools require special rake and clearance from 3 to 5 deg. more than is common practice with metal. Die heads do not require special rake and clearance. They are operated at a relatively slow speed and are backed off a short distance in every inch of threading. Neither taps nor dies require special grinding. High speed and ground taps produce the best results. Tap-drill sizes recommended are the same as those commonly used for metal.

Drilling.—The cutting point of the drill should have an included angle of about 55 deg. Rapid feed prevents the drill from lagging. For holes more than 1/2 in. deep the drill should

be withdrawn momentarily to cool and remove the chips. The minimum preferred speed is 1,200 r.p.m.

Gear Cutting.—Teeth may be cut on a hobbing or milling machine or a shaper. Assuming a 3-in. hob with 10 teeth, the

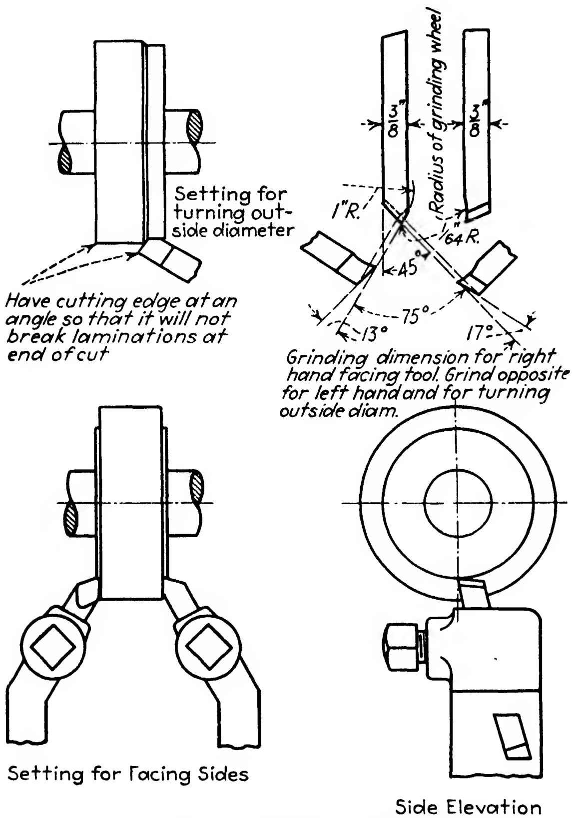


FIG. 74.—Tools for turning Formica gear blanks.

speed would be 150 ft. per minute and the feed from 0.090 to 0.110 in. per revolution.

MICARTA

Micarta is a product of the Westinghouse Electric & Mfg. Co. It is made of either a paper or fabric base and a synthetic resin. The data following are from the company's experience.

Turning.—In general, high speeds, fine feeds, and light cuts

are best. If high-speed-steel tools are used, the speed should be from 100 to 125 ft. per minute. Where roughing and finishing cuts are taken, a high-speed-steel tool is not essential for the first operation but should be used for the second. About 0.010 in. of stock should be left for the finishing cut. An exhaust system should be provided.

Threading.—Chasers should be made without the hook used in cutting steel. Plenty of chip clearance should be used on taps and dies as Micarta has a tendency to choke the tap. No undercut or hook on the flute is necessary, but a slight hook on the lead is required to start the chip to curl. High-speed taps are preferred except in extremely small sizes. Ground taps are not usually necessary. About 70 per cent full thread is recommended. Standard tap-drill sizes are satisfactory. Small holes (under 1/4 in.) are machine-tapped at a speed of 200 r.p.m. or under. Larger holes are hand-tapped. Medium-size holes are tapped with a slow-speed drill press fixture at 40 to 60 r.p.m.

Drilling.—The acute angle of drill should be 49 to 50 deg. The face of the lip should have the hook removed as for cutting brass. The grade of Micarta has an effect on the cutting speed and feed. For Micarta with a cloth or paper base, holes up to 1/4 in. in diameter can be drilled at a speed of 1,600 r.p.m. The asbestos grade requires slower speeds of 800 to 1,000 r.p.m. Holes from 1/4 to 5/8 in. require speeds from 500 to 800 r.p.m. For holes from 5/8 to 1 in. the speed should be from 80 to 200 r.p.m., and above 1 in. in diameter a counterbore should be used. Use hand feed. On small holes and thin material a feed suitable for wood can be used. When drilling straight through on thick material, it is necessary to clear the drill about every 1/2 in.

Milling.—A standard cutter may be used at a speed and feed corresponding to those used for bronze or soft steel.

Punching.—Dies should be designed the same as for punching metal, except that smaller clearances should be allowed. In cold punching it is desirable that this clearance be small and approach a sliding fit. Maximum punching thickness for any grade is 1/8 in. Heating the stock from 210° to 230°F. will insure better quality punching.

Sawing.—Material up to 1 in. thick should be cut with a 10-in. saw working at 3,000 r.p.m. Above 1 in. thick a 16-in. saw running at about 1,600 r.p.m. is satisfactory. Roughing cuts

should be made with a saw having a bevel tooth, seven to the inch, while for finishing a smooth saw similar to that used for metal (no set) should be used.

TEXTOLITE

Textolite is a product of the General Electric Company. It consists of canvas coated with a synthetic resin as a binder.

Turning.—The tools used by the company comprise tungsten carbide tips mounted on $\frac{3}{8}$- or $\frac{5}{8}$-in. square bits. These tools are ground with no top rake and with $6\frac{1}{2}$ deg. clearance on the end and sides. A very keen edge must be maintained. When tools become too dull to cut Textolite, they will still work satisfactory on metals.

The cutting speed is usually the highest speed that the machine will handle, up to 500 or 600 ft. per minute. Roughing cuts range from $\frac{1}{16}$ to $\frac{1}{8}$ in., finishing cuts not less than $\frac{1}{64}$ in.

Threading.—The rake and clearance on chasing tools are the same as those used on turning tools. Special grinding is not necessary for taps and dies. High-speed ground taps have been found to give the best results. Tap-drill sizes are the same as those used for steel. Most work is tapped by hand. For production tapping it is recommended that a coolant of very light oil or turpentine be used.

Drilling.—Best results are obtained with twist drills having a long lead and with the lips ground thin and with little rake. An air blast is used to cool the drill. Most drilling work is done with hand feed. For a $\frac{3}{8}$-in. drill the speed is 1,800 r.p.m. With automatic feed, using a No. 45 drill operating at 3,600 r.p.m., a feed per revolution of 0.002 to 0.003 in. has been found satisfactory.

Punching.—Textolite may be punched readily in thicknesses up to $\frac{1}{8}$ in. The die should be relieved on a taper of about $\frac{1}{4}$ deg. to a distance of $\frac{1}{8}$ in. below the surface. This relief will minimize splitting around the edge of the punched part. Punched holes usually contract slightly, so that it is necessary to make punches slightly larger than the hole desired. The increase in punch diameter is equal to approximately 3 per cent of the thickness of the material. When thick pieces are being punched, it is desirable to use a shaving die.

Some grades of Textolite can be punched cold, but it has been found by some manufacturers to be worthwhile to heat all material before punching. This is usually done by laying the strips on a steam plate which should not have a temperature higher than 300°F. The Textolite should not be left on the plate for an extended period.

HARD RUBBER[1]

Turning.—Shapes of cutting tools are given in Table XXVIII. High-speed steel is recommended for turning tools. Tungsten carbide tools are used when the savings justify the expense and because they avoid frequent resharpening, improve the finish and accuracy. Where the accuracy required demands them, diamond tools are used, but they cannot be employed on interrupted cuts. With coolant, turning, facing, and boring operations can be done at a speed of 300 ft. per minute, whereas when done dry, the speed is reduced to 200 ft. per minute. A large screen area should be provided in coolant reservoirs to remove floating rubber particles. It is recommended that wet grinding wheels be used in place of turning wherever possible.

Threading.—Tables XXVIII and XXIX give information on the grinding of chasers as well as the speeds recommended. High-speed taps and chasers are preferred. No special table of tap-drill sizes has been developed. When cutting coolant is not available or practical, machine oil should be applied to taps and dies. If the tolerances are very exact the taps should be made 0.002 to 0.003 in. oversize for taps up to the No. 6-32; 0.005 to 0.006 in. oversize for taps up to 3/8 in., and 0.006 to 0.010 in. oversize for taps from 3/8 to 1 in.

Drilling.—Feeds and speeds for drilling are given in Table XXIX. High-speed drills are preferred. A greater helix angle than with steel increases the cutting speed and drill life. An ideal helix angle is from 35 to 40 deg. but is available only in small diameters and in drills made by the Cleveland Twist Drill Company. Drill sizes below 1/4 in. should be ground to an angle of 45 deg. Above the 1/4-in. size the standard 59-deg. angle is used. The lips should be snubbed or ground flat to prevent digging in. Flat drills may be used for odd sizes or large diameters. The same coolant as applied for tapping should be used.

[1] Courtesy of American Hard Rubber Company.

TABLE XXVIII.—TOOL SHAPES FOR HARD RUBBER

Operation	Tool	Top rake, deg.	Side rake, deg.	Clearance, deg.	Notes
Turning	Steel (lathe)........	None	None	10 to 20	If consistency of stock causes tool to tear, tilt forward to increase clearance and provide negative rake of 5 to 10 deg.
	Form tools.........	None	None	15 to 20	
	Tungsten carbide tip.	None	None	10	
Facing	Roughing diamond..	None	None	10	Round nose 3/32 in. radius.
	Finishing diamond..	None	None	10	Round nose 1/64 in. radius.
Threading	Tap...............	Snub slightly			Grind flutes deep as possible.
	Die................	Snub slightly			
	Diehead chasers.....	Negative rake, 15 deg.			

TABLE XXIX.—SPEEDS FOR MACHINING HARD RUBBER

Drilling

Diameter, in...	To 3/16	1/4	3/8	1/2	5/8	3/4	1
Speed, r.p.m...	4,000	3,000	2,000	1,550	1,200	1,000	750
Feed, in.......	0.005	0.006	0.008	0.010	0.011	0.012	0.014

Tapping (pipe sizes)

Nominal size, in................	Up to 2	2½	3	4
Speed, ft. per minute............	200	100	75	55

Turning, facing, and boring

With no coolant, 200 ft. per minute—with coolant, 300 ft. per minute

Sawing.—Bandsaws 0.035 in. thick by ⅞ in. wide, 5 to 8 points per in., running at about 3,400 ft. per minute, give good results for rough sawing. For cutting off small rods, tubes, and strips, abrasive wheels such as the Norton Grain 30 Grade R8, or a Carborundum "Carbo Redmanol" 70C-6V are suitable. The wheel should be about 8 in. in diameter, 1/16 in. thick, running at 10,000 ft. per minute. For sawing panels or sheets, the following

saws may be used: a 14-in. diameter by 1/8-in. thick Carborundum 50-C4 or "Carbo Redmanol" 36C-2D wheel, running at about 12,000 ft. per min.

Grinding.—Either wet or dry grinding may be done. If hard rubber is ground wet with water or with cutting lubricant, the surface is black and smooth but if ground dry the surface will be more or less rough and will be brown in color. Below are listed a few of the wheels used for various types of work:

Article	Wet or Dry	Wheel
Penholders—pipe bits.........	Wet	60 N. Crystolon or Alundum
Rods or tubes................	Wet	60 M Crystolon
Rods or tubes................	Wet	36 L Staralon
Sheets up to about 1 in. thick.	Dry	50 K Silicon
Sheets over 1 in. thick........	Dry	24 L Alundum

Tables XXVIII to XXX give valuable information on the machining of hard rubber.

TABLE XXX.—DEPTH OF CUT AND FEED

Surface	Depth of cut, in.	Feed, in.	
		Turning	Boring
Rough cut	1/16	0.025	0.018
	3/32	0.023	0.016
	1/8	0.020	0.014
	5/32	0.018	0.012
	3/16	0.017	
	7/32	0.016	
	1/4	0.015	
Finish cut	1/32	0.012	0.009
	1/16	0.012	0.009
	3/32	0.011	0.008
	1/8	0.010	

FIBER

Turning.—Fiber is an extremely hard and tough material, and to obtain the best results in machining it is necessary to keep the cutting edges of tools in good condition. The material is slightly elastic and tends to impinge against the back of the tool and to generate heat. As a general rule, tools for cutting fiber

should be ground about the same as for cutting brass. The peripheral speed should be about 30 per cent faster than for cast iron, using a coarse feed and a wide-nosed tool. Large clearance but no rake should be employed. Lubricant is not needed. Diamond cutting tools are satisfactory for light cuts on close work.

Fiber tubes and rods can be successfully machined in automatic screw machines or hand turret lathes. When tubes of the correct size can be secured they will generally give better results than rods. The following are the recommended cutting feeds on automatic screw machines:

	In. per Rev.
Drilling	0.007 to 0.010
Turning	0.010 to 0.015
Forming	0.0015 to 0.002
Cutting-off	0.002 to 0.003

Threading.—Both solid and self-opening dies are used, but the self-opening type is recommended for all work except that with short thread lengths where the threads may be torn off in opening the die. A smoother thread is obtained by stoning the dies to a negative rake of 7 deg. and slightly dulling the cutting edge with a V-shaped stone. Tap-drill holes should be made from 0.002 to 0.006 in. larger than commonly specified when tapping brass or steel. In selecting the tap drill it should be remembered that a drill will cut fiber a few thousandths smaller than itself unless ground slightly off center. A very little oil will give an easier flow of chips.

Drilling.—Run drills at the highest speed possible without burning the tool. A $\frac{1}{4}$-in. drill should run at 2,500 r.p.m. and a No. 60 drill at 10,000 r.p.m. High-speed or special bakelite drills with greater spiral, narrow web, and wide flutes are recommended. The drill should be ground with a liberal clearance and should not be forced. Fiber should always be drilled perpendicular to the grain when possible. Ordinarily a drill cuts smaller than itself in fiber, making the hole a few thousandths smaller than the drill. This may be overcome by grinding the drill slightly off center. Digging in may be minimized by stoning the cutting edge to give it a slight negative rake.

Milling.—With standard milling cutters high speeds and feeds give the best results as to both finish and length of time between

grinds. Two-bladed fly cutters for form work should be run at higher speeds but with slower feed. A high speed and coarse feed will throw the chips away from the work and will prevent a rubbing action that dulls the tool quickly. For deep slots use side-milling cutters because fiber will bind if straight-side cutters are employed.

Sawing.—A smooth polished edge can be obtained with a hollow-ground circular saw without set to the teeth. A satisfactory circular saw for stock up to ¼ in. is 14 in. in diameter, with 110 to 120 teeth, and from ⅛ to $\frac{5}{32}$ in. thick at the outer edge. This saw should be run at 2,500 to 3,000 r.p.m. Band saws with 5½ points per in. and 19-gage thickness are satisfactory. The widths vary from ¼ in. for scroll sawing to 1¼ in. for heavy sheet sawing. A band saw should run at about 4,000 ft. per min., and will last from 1 to 1½ hr. on ⅛-in. fiber, and ½ hr. on ¾-in. fiber before sharpening is necessary.

Bending and Forming.—Fiber should always be bent parallel to the grain (long way of the sheet), because it is difficult to bend fiber across the grain without breaking. It is general practice to soften the material by immersing in hot or cold water and then drying it out in heated forms under sufficient pressure to keep the shape desired. If the material can be steamed instead of immersed, it will require less time to set.

Punching.—Blanking, piercing, and shaving operations on fiber can be done with ordinary punch presses. The punches should be a close fit in dies for best results. Fairly smooth edges can be obtained in stock up to ⅛ in. thick without heating. Above this thickness it is advisable to heat the stock to 180°F. When a rough edge is not objectionable, thicknesses of ⅜ to ½ in. can be punched. Because of the necessity for frequent grinding, dies for fiber should not have any taper clearance. In rough punching when accurate dimensions are required allowance should be made for the punch to produce a hole 0.001 to 0.008 in. smaller than itself and for the blank to be 0.001 to 0.0008 in. larger than the hole in the die plate, the allowance increasing with the thickness of the stock.

Shaving.—The cutting edge of shaving dies should be about 45 deg. No clearance is given to the first ¼ in. of the die, and dies can be ground without changing size. A better edge on the part can be had by using a roughing cutter and then a

finishing cutter. Fiber has a tendency to check. Elimination of the difficulty will be obtained by heating it to 180°F. If the cutting edge on a shaving cutter is mouthed out very slightly with an oil stone, the stock will bind slightly in passing through, will prevent chatter, and will tend to smooth and polish the edges. Stock up to 1¼ in. thick can be smooth punched by successive shaving operations.

CAST PLASTICS

Cast plastics, or more properly cast synthetic resins, are now being used commercially for parts that require machining and that are to be made in such small quantities that dies and molding equipment are not justified. They are somewhat softer than molded materials and can, consequently, be machined easily. While possessing the desirable properties of molded materials, they may be turned, drilled, sawed, ground, threaded or tapped, embossed, carved, faceted, and highly finished by polishing.

Machining.—Stellite and tungsten carbide and tantalum carbide tools, are preferable to tool steel for machining. While the material cuts like ivory or wood, it heats rapidly and may burn the tip of an ordinary tool. As in cutting wood or ivory, tools with a negative rake are used to prevent "biting," and a surface speed of about 280 ft. per minute has proved best. High speeds and feeds are advisable. Tools should be ground with generous clearances and should produce a shaving cut. It is important that tools be shaped to provide rapid chip removal. High-speed steel tools work satisfactorily with an emulsified oil as lubricant, which should be free of all caustics. Turning is done similarly to wood turning, the material machining with a shaving, instead of crumbling. Lathe cut-off tools may be used for cutting off, as may any common or band saw, but a thin high-speed grinding wheel is most economical. For average work, a band saw should have 14 to 15 teeth to the inch, and the surface speed should be 1,300 r.p.m. or more. The band saw should be about ½ in. wide and just soft enough to file. A good saw will run 8 to 15 hr. before requiring resharpening. The fine structure of the material prevents the saw from "running," permitting accurate cutting of contours. One manufacturer uses a specially bonded bakelite wheel for cutting rods

up to 2 in. in diameter, claiming better results than those possible by sawing.

Either a flat or twist drill may be used for drilling, but the cutting lip must be ground off as in brass or aluminum drilling, or the drill will "bite." Tapping may be done without lubricants, just as cast iron is tapped. Small screws will tap their own holes easily.

Forming.—Cast sheet may be formed or bent to any shape except very sharp corners. The sheet should be immersed in hot water from 3 to 10 min. according to thickness, only long enough to warm it, as too long an immersion tends to harden it. The water should be near boiling temperature. To give the material greater flexibility, add 20 per cent glycerin to the water. Another good method of softening for forming is to use 250-deg. compensator oil as a heating medium. The formed material should be cooled in the die to hold its shape. In storing, avoid sunlight and hot rooms. Stacked thin sheets should be weighted; rods stored flat, not upright.

The Marblette Corporation and the American Catalin Corporation give the following suggestions for machining cast plastics:

Stamping.—Dies similar to paper-cutting dies should be used, and the edges of the punch and die should be kept very sharp. Sheets are prepared for stamping by immersion in hot water with 20 per cent glycerin added, or by a hot plate or other heating device on the die. The sheets should be immersed 3 min. for each 1/8 in. of thickness. For embossing, use a bronze or steel die, heating it preferably with an electric grid to about 200°F. In some cases it is also advisable to heat the material.

Sanding and Grinding.—Sandpaper, garnet paper, belts, or fine abrasive wheels may be used on regular wood- or brass-grinding equipment. The finer the grit, the smoother the work. Some fabricators use water as an emulsion while grinding, but when grinding is done dry, an exhaust fan is advisable. Grinding wheels of about 14 in. in diameter should run at about 1,800 r.p.m.

Ashing.—Use an ordinary buffing wheel made of muslin disks about 12 in. in diameter, running at approximately 1,800 r.p.m. Sometimes a corn husk or carpet rubbing wheel is preferred. These wheels should run in a solution either of fine ashes and water or of pulverized pumice and water. The ashing solution is kept in a shallow pan under the buff so that the buff

just about touches it; thus the mud can be applied by hand or with a flat trowel.

Polishing.—Use a regular buffing wheel made of a muslin disk, usually about 12 in. in diameter, operating at 1,800 r.p.m. Tripoli polishing wax produces a high finish. Some people prefer carnauba wax and other fabricators use steric acid or palmitic acid for an extra high lustrous finish. After the polishing operation, it is often advisable to finish with a soft, dry buff. Smaller articles can be polished in a tumbling barrel. This is generally made of hard wood, often lined with heavy felt or leather, revolving at about 50 r.p.m.

Cast plastics are noninflammable, nonwarping, unaffected by alcohol, water, or oils, resist common acids. They have dielectric strengths between those of glass and mica, tensile strengths around 8,000 lb. per square inch, compressive yield points around 10,000 lb. per square inch, and specific gravity about 1.29. In addition, they are available in any desired color and shape. They are cast in rod, tube, block, or special casting forms. The materials are either opaque, translucent, or transparent throughout the entire range of colors, in plain or mottled effects. Mottling, when used, extends entirely through the piece, so that subsequent machining will not reveal blank-color spots. One manufacturer lists 56 "standard" colors, from which may be obtained an infinite number of variations by varying composition of the mixture. Hardness may also be varied to some extent.

Machining Laminated Plastics.—The increasing use of plastics of various types and in different forms means that they are likely to find their way into many more shops than formerly so that it is advisable to know something about the way in which they are turned and otherwise machined in present-day practice. In general it is safe to say that high speeds and light cuts are to be recommended in nearly all cases. This, according to the Synthane Corporation, means cutting speeds in the neighborhood of 800 to 900 surface ft. per minute and feeds of 0.004 to 0.005 in. per revolution of the work.

Carbide-tipped tools are used for turning while Stellite has been found satisfactory for threading this material. The threading tool is given a zero rake and set about $\frac{1}{32}$ in. below the center of the work.

CHAPTER XXIV

FUNCTIONS OF CUTTING OILS

Cutting oils have several functions depending on the metal being machined and the kind of operation being performed. These functions are:

To provide lubrication between tool and work.

To dissipate heat and so cool the tool and the work.

To reduce the power consumed in cutting.

To increase the life of the tools.

To secure a good finish and accurate dimensions.

To prevent corrosion.

To flush and carry away the chips.

Cooling may be more important than lubrication in some operations, whereas in other the reverse is true. Tough material wears the tool back of the cutting edge. This can be reduced by proper lubricant. Chips break as they come off and so vary the pressure on the work. A good cutting oil will help to maintain a more uniform pressure and so aid in securing a good finish and in maintaining accuracy. Metals and operations that produce chips which break into short pieces do not require so great a film strength in the cutting oil as those which roll off a long chip. Long curling chips bear on the top of the tool for an extended period and tend to destroy the oil film.

Causes of Heat.—Heat from the cutting of metal is due to the tearing of metal being machined and the friction between the tool and work, both at the cutting edge and between the chip and the face of the tool. For this reason the kind of metal being cut, the operation being performed, the cutting speed, the feed, and the depth of cut, all affect the heat generated.

The types of cutting fluids generally used for cutting metal are alkaline solutions, soluble oil emulsions, straight mineral oils, straight lard or other fatty oils, blends of mineral and fatty oils, sulphurized fatty oils blended with mineral oils, and sulphurized mineral oils. An air jet may perhaps also be considered as a cooling fluid when blown on the tool and the work.

Alkaline Solutions.—Alkaline solutions consist of water to which a small proportion of mild alkali has been added to minimize corrosion. They are not used to a great extent and are generally confined to operations such as grinding, where cooling and laying of dust are of greater importance than lubrication.

Soluble Oils.—Soluble cutting oils vary considerably in composition, but the majority of them consist of mineral oils and oil-soluble emulsifiers, such as soaps or sulphonated fatty oils, which make them mixable with water. Soluble oil emulsions are applicable where the cooling requirements predominate, although by virtue of their mineral and fatty oil content they are capable of forming stronger films and assuring greater protection against corrosion than water or alkaline solutions. As they may be diluted with water in various proportions, depending upon the cutting operations, they are economical to use where applicable.

Mineral Oils.—Mineral oils are suitable for light duty cutting of some steels and for difficult machining operations on nonferrous metals such as aluminum and copper where both lubrication and cooling may be necessary, but neither requirement is severe. They are used to some extent for automatics where an emulsion may cause trouble by getting under the turret and replacing the lubricating oil, thus necessitating a shutdown for cleaning. Straight mineral oils are not satisfactory for severe cutting requirements, but where they are used, best results will be obtained from relatively low viscosity oils which have good penetrating and cooling properties.

Animal and vegetable oils, which are generally classified as fatty oils, are superior to straight mineral oils in their ability to lubricate under extreme pressures. The greater "oiliness" of fatty oils, as compared with mineral oils, is probably caused by their greater affinity for metals which makes them more difficult to rub off metallic surfaces.

Lard Oil.—Lard oil is the most commonly used fatty oil in this country, although rape-seed and other oils are used in parts of the world where they are lower in price and more available. Other fatty oils, such as fish oils and degras, are satisfactory from a metal-cutting standpoint, but their odors make them objectionable. Lard oil was formerly used straight for most severe cutting operations, but is now generally blended with

mineral oils in various proportions to provide the necessary film strength. Oleine, or commercial oleic acid, is a fatty acid derived from animal oil which is also used to a limited extent in place of lard oil for blending with mineral oils.

Sulphur, when properly combined with mineral or fatty oils, has the property of imparting an oiliness which, in some instances, exceeds that of straight lard oil. This ability of sulphur to increase the film strength of oils is, probably caused by the great affinity of sulphur and its compounds, formed by union with the oil, for metals.

Sulphurized Oils.—Sulphurized oils are rapidly gaining favor for cutting alloy and medium- and high-carbon steels. Results indicate that, if properly made, they are superior to other types of cutting oils for practically all machining operations on steels. However, they do not appear to have any advantage in cutting cast iron and nonferrous metals and are not desirable for copper and its alloys because of the tarnishing effect of the sulphur compounds on the metal.

The earlier sulphurized oils were dark in color, which hindered the inspection of the work by the operator, and their odor was often disagreeable. However, relatively light-colored highly sulphurized oils which do not have an appreciable odor are now obtainable. All sulphurized oils have a characteristic odor which is usually more pronounced as the proportion of sulphur is increased.

Another problem encountered with earlier sulphurized oils was the difficulty in getting more than a small percentage of sulphur permanently incorporated with the oil so that it would not precipitate. This problem has been overcome, and oils containing relatively high proportions of sulphur are now available. In many instances a highly sulphurized base oil is used straight for very severe requirements, and diluted with paraffine or light machine oil, for less difficult work.

Where cooling is more essential than lubrication, soluble oils are used. If lubrication is most important, compounded and sulphurized oils are best. A straight mineral oil is usually satisfactory where both cooling and lubrication are required in moderation. Soluble oil emulsions are more apt to leave a gummy deposit.

These varying conditions make it advisable for a large plant to use several different cooling oils or compounds. Small shops, however, will usually compromise on one oil which gives good average results. A mineral-lard oil combination with from 10 to 25 per cent of lard oil will work very well on both ferrous and nonferrous metals. It is also possible to find a soluble oil which may be satisfactory at somewhat lower cost. For ferrous metals only, a soluble oil and a heavy sulphurized mineral oil will usually take care of nearly all kinds of work. The sulphurized oil may be used for heavy cutting and it can be diluted, or cut back, with parafine or light machine oil for lighter work. This will reduce the kinds of oil to two, for handling all ferrous work in the average shop.

Shape of Chip.—The shape of the chip helps greatly in selecting the best cutting oil. A long curling chip that bears heavily on the tool, indicates tough material and needs a heavily compounded or sulphurized oil. If the chip bears hard but breaks off just above the tool, a lightly sulphurized or compounded oil will answer. Metals where the chips break quickly, such as cast iron, can use a soluble oil emulsion or be cut dry.

In grinding, cooling is most important and the weakest emulsion that will prevent corrosion is usually satisfactory. Rusting is the most common difficulty with emulsions. A small percentage of soda ash, potassium bichromate, or similar materials will help prevent rust but should not be added without consulting makers of the oils used.

Cutting lubricant or coolant should fall directly on the chip. It should be applied in a large stream to dissipate the heat quickly, as in Fig. 75. If the stream strikes the work above the cut, it is easily deflected, as in Fig. 76, and does very little cooling of the work or tool.

Reclaiming Oil.—Large plants reclaim used cutting oils, first with centrifugal separators which remove the oil from the chips, and then employing suitable apparatus for cleaning and purifying the oil. Modern apparatus of this kind sterilizes the oil before it is used again. This prevents skin infections that cause discomfort and may possibly lead to compensation claims. The first sign of such infection should be looked after by a physician. Infected men should be kept away from the cutting fluid. All operators should use soap and water liberally.

This will usually prevent infection. Oil-soaked garments should be changed at least once a week. Disinfectants sometimes aid in preventing infection but should only be used on advice of the plant physician, as some types of disinfectants are undesirable.

Cutting Lubricants or Coolants.—Lard oil was one of the earliest cutting lubricants used and is still used although mostly in combination with other oils and ingredients, such as sulphur. Lard oil is often blended with petroleum and called mineral lard oil. The percentage of lard oil varies, frequently being as low

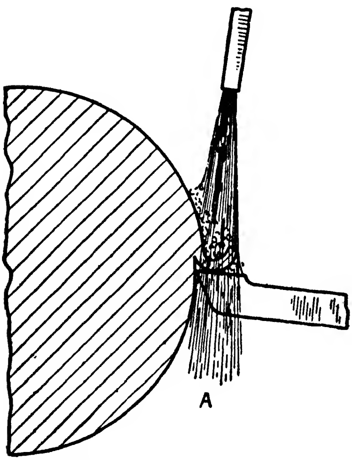


FIG. 75.—The right way.

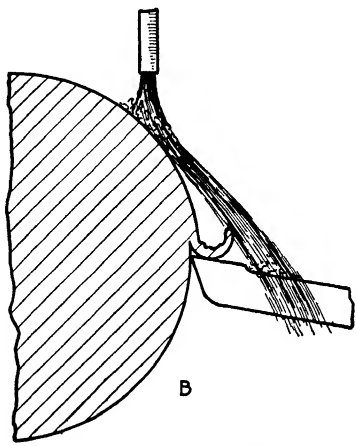


FIG. 76.—Ineffective.

as 5 to 10. In such cases it is important to prevent the lubricating oil from the bearings from leaking into the cutting oil, as the percentage of lard oil will be appreciably reduced. Mineral lard oil is frequently used in reaming to give a smooth surface.

When the work of a machine includes several operations, it is cheaper to use the cutting lubricant best suited for the hardest operation than to change. The time and cost of changing will usually more than offset the saving from the cost of oil.

Water Compounds.—Cutting emulsions or water compounds are used widely in both drilling and milling operations. Many water compounds tend to get rancid so that the water tanks should be cleaned and new compound mixed as frequently as necessary. Many shops find it best to do this about twice a month.

Airplane-cylinder Coolant.—Machining the fins on air-cooled airplane cylinders is not an easy job, it being equivalent to a bank of cutting-off tools that leave a thin fin between each tool. In the Kinner engine the fin is 0.040 in. thick and 24 cobalt high-speed tools are used. A mixture of paraffine and amber oil in equal parts serves for 100 cylinders per tool grind as against 15 cylinders with a previous compound. These oils can be obtained from several oil companies. On the larger cylinders the tools remove 1,500 lb. of chips per hour.

Cutting Fluids for Various Operations.—The chart of cutting-fluid applications on page 440 was compiled by J. D. Roney and G. L. Sumner of the Westinghouse Electric & Mfg. Co. It is self-explanatory and covers a wide variety of machine-shop operations as well as a variety of materials. Taking lathe work on stainless steel, we find that K (which means water emulsions) is recommended for all operations. The same is true of monel metal. If we have bronze rod to cut in a chucking machine, we are shown that water emulsions are best for most cutting operations, except for threading, tapping, and reaming, for which mineral lard oil in 11 per cent solution will give better results. It is also interesting to note that 1 per cent of sulphur is recommended for a number of operations.

Where any considerable quantity of oil is used, it pays to sterilize and filter it frequently enough to keep it from becoming rancid and otherwise objectionable.

A Corrosion-preventive Cutting Compound for General Shop Use.—The Bullard Company use the following cutting compound on milling machines, lathes, boring mills, and grinders.

Water, after being boiled and allowed to cool to room temperature, is softened with a weak alkali such as borax. The borax saponifies the soluble oil which should be added next. Finally, a small quantity of trisodium phosphate is added to emulsify the solution. A recipe for 50 gal. of this solution is as follows.

47 gal. boiled water (cooled to room temperature).
3 lb. borax.
3 gal. soluble oil.
1 lb. trisodium phosphate.

The solution should be made up in the order of listing the ingredients.

This cutting compound, according to Works Manager Thomas E. Dunn, gives results as follows, compared with the previous practice:

1. Milling cutters, reamers, drills, cutting tools and grinding wheels have 30 per cent longer life because of the superior lubricating and heat-absorbing qualities of the compound.

2. Machined parts are left with a thin film of oil that prevents rusting for a considerable period of time.

3. Tables, ways, and other parts of machines, as well as the cutters and tools, are left with a thin film of oil that prevents rusting.

4. Savings made in the amount of soluble oil used approximate one-third, since the company has determined the exact quantity of oil to be used in this universally applicable compound.

5. No tendency to develop odors or "slime" has been discovered in the compound used for a period of four months.

6. When this solution is employed on grinders, the wheel cuts freely and the work does not tarnish or rust.

Coolant in Deep-hole Boring.—Boring and finishing holes in great lengths of shafting, oil-well rods, etc., require the delivery of a specified amount of cutting fluid to the cutting tool as well as velocity, if the best results are to be secured. The function of a coolant on this work is not only to reduce the heat generated by cutting, but also to remove the chips quickly and effectively from the annular space between the boring bar and the wall of the hole being bored.

To do this, the cooling fluid, such as one part soluble oil to 16 parts of water, must be delivered in sufficient quantity at a known velocity. The quantity of fluid necessary is determined by the area of the annular space and the thickness of the chips being cut. The pressure required is controlled by the diameter and number of holes drilled in the boring tool back of, or around, the cutter. If the holes are too large the velocity will be lacking, if too small the quantity will be insufficient to start the chips. The capacity of the pump also enters—the one generally used is a self-contained unit carried on the machine, and its capacity is, therefore, limited. To overload it to obtain either volume or pressure delays the job. Where a central pumping station of sufficient capacity is available, the size and strength of the hose are usually the limitations. If the holes in the boring head are too

small, the hose may burst trying to supply the volume; if they are too large, the hose cannot supply the velocity.

TABLE XXXI—VOLUME AND PRESSURE OF COOLANTS

Thickness of chip, in.	Diameter of bore, in.	Diameter of bar, in.	Gallons per min.	Holes drilled		Pressure, lb.
				Diameter, in.	Number	
1/16	1 1/4	1	0.8	1/8		
	1 1/2	1 1/4	0.8		1	20
	1 3/4	1 1/2	0.9			
	2	1 3/4	1.0			
1/8	1 3/4	1 1/4	2.5	1/8	2	
	2	1 1/2	2.8		2	20
	2 1/4	1 3/4	3.2		3	
	2 1/2	2	3.2		3	
1/4	3	2 1/4	10.5	1/4	2	
	3 1/2	2 3/4	11.5		2	28
	4	3 1/4	11.5		3	
	4 1/2	3 3/4	12.5		3	
	5	3 3/4	16.5	5/16	2	35
	5 1/2	3 3/4	20.0		2	
3/8	3 1/2	2 1/2	23.0	5/16	3	
	4	3	25.0		3	
	4 1/2	3 1/2	28.0		3	
	5	4	28.5		4	30
	5 1/2	4 1/2	29.5		4	
	6	5	30.5		4	
	7	5	42.0	3/8	3	45
	8	5	54.0		4	
1/2	4 1/2	3	53	3/8	4	
	5	3 1/2	57		4	
	6	4 1/2	63		4	40
	7	5 1/2	66		5	
	8	6 1/2	73		5	
	9	6 1/2	92	1/2	4	50
	10	6 1/2	101		4	

While the annular clearance between the boring bar and the hole being bored is a controlling factor, little thought is bestowed upon the relative size of the two. In bores of relatively small

diameter the inclination is to use a bar as large as possible, leaving just sufficient room for the chips to escape. In large holes the thought behind the selection of the bar is strength. If the velocity and volume of fluid are suited to the proper cutting conditions, it is largely the result of accident or at best an inspired guess.

As a result of an investigation of the subject, along the lines of current shop methods, Victor Tatarinoff, of Pilsen, Czechoslovakia, has compiled a table which establishes definite relations between the different factors involved in deep-hole boring.

The investigation showed that the velocity of fluid required depended upon the thickness of the chip being cut, and that the relation between the velocity V and the thickness c may be expressed in the simple formula: $V = 1.02\sqrt{8c}$. This formula allows one to compute the quantity of cutting fluid to be delivered, together with the necessary working pressure. Data showing this information are given in the accompanying table.

In the larger sized holes the size of the boring bar is predicated upon strength and not upon clearance between it and the wall of the bore. Nevertheless the necessary velocity of fluid must be maintained to prevent the accumulation of chips at some point along the bar.

A central pumping station is considered preferable to the portable pump; also, it seems that the most economical method is to regulate the quantity of water delivered to the pipe supplying the boring bar. A by-pass valve is not recommended, as no economy results from this arrangement, especially where a centrifugal pump is used. Where there is sufficient volume of work, an accumulator type of water system is good economy.

Other Opinions on Cutting Fluids.*—It is difficult to get conclusive data as to cutting fluids for machine work. Widely differing materials and operations as well as the opinions of users add to the difficulties. Some object to a fluid because it is slippery, or obscures the work, or irritates the skin of the worker, or has a disagreeable odor. Then, too, the seller frequently influences the buying with little regard to the real merits.

No cutting fluid can be best for all conditions. Water emulsions are not considered desirable on oil-lubricated automatics

* J. D. Roney and G. L. Sumner, Westinghouse Electric & Mfg. Co.

because of the danger of water seeping into the bearings. And on cam- and spring-actuated machines water emulsions may cause sticking of the slides, especially if allowed to remain on the slides over night or over a week end.

When a job requires several operations, it is not economical to change the cutting fluid but rather to use the one that gives best results on the hardest operation. Use the one that works best in the tapping, even if it costs a little more than those which might answer for the turning operations.

Tool Life.—Tool life, or the number of pieces per grind, is an important factor in selecting lubricants, depending largely on the material to be cut and the kind of operation. Reaming and threading tools should be most carefully considered, as these are the most expensive in the majority of cases. The cutting fluid also affects the finish and is to be considered on exposed parts. Plain water gives a beautiful polish on mild steel, being formerly used in finishing steel shafting. Its rusting qualities, both on the work and on the machine, prevent its use in most cases. The life of cutting fluids varies greatly so that short tests are of little value, particularly where water compounds are employed. This may be due to the separation of the ingredients, which is frequently hastened by oil seeping from leaky bearings of the machine.

Water compounds have a distinct place in machining, depending largely on the work to be done. Drilling, in which the function is largely that of cooling, is an excellent place for water compounds. Water emulsions are also largely used in milling operations. Losses through splashing and adherence to chips require periodic additions. And, as most water emulsions develop rancidity, they must be entirely replaced at intervals. It is usually desirable to clean the sump or tank about twice a month and replenish with a new mixture.

Cutting oils are just as necessary as emulsions. Lard oil was probably the earliest cutting medium and is still in use to a limited extent. Combinations of lard oils with other oils and with sulphur are being used satisfactorily in many places where it was thought that only lard oil could be used. Mineral lard oil is usually made by blending lard oil and petroleum in various proportions. Where the oil used in lubricating the machine can drain into the cutting-oil reservoir, the proportion is materially

TABLE XXXII.—CUTTING-FLUID APPLICATION CHART

Type of machine tool	Aluminum	Copper	Cast iron	Mal. iron	C. R. steel	Axle steel	Tool steel, annealed	Heat-treated steel	Stainless steel	Monel metal	Soft brass	Cast brass	Bronze rod	Cast bronze	Cast steel	Wrought iron	Sheet iron	Fiber	Hard rubber	Micarta
Lathes	1-2-3-4 5-6 F	3-4-5 D	3-4-5 G	1-6-K 3-4-5-G	1-6-K 3-4-5-G	1-6-K 3-4-5-G	1-6-K 3-4-5-I	1-6-K 3-4-5-I	1-6-K 3-4-5-I	1-6-K 3-4-5-I	1-2-3 4-5-6 K	1-6-K 3-4-G 5-K	1-6-K 3-4-5-D	1-6-K 3-4-5-I	1-6-K 3-4-5-I	1-6-K 3-4-5-I and G	....	3-4 M	..	6 L
Semi-auto. lathes	1-2-3 4-5-6 F	1-2-6-E	....	1-2-6-K	1-6-K	1-6-K	1-6-K	1-6-K	1-6-K	1-6-K	1-6-K	1-6-K	1-6-K	1-6-K	1-6-K	1-6-K				
Turret lathes	1-2-3 4-5-6 F	1-2-3 4-5-6 D	3-4-5	1-2-6-K 3-4-5-G	1-6-K 3-4-5-G	1-6 3-4-5-G	1-6-G 3-4-5-I	1-6-G 3-4-5-I	1-6-G 3-4-I 5-G	1-6-G 3-4-I 5-G	1-6-K	1-6-K 3-4-5-G	1-6-K 3-4-5-G	1-6-K 3-4-5-D	1-6-K 3-4-5-I	1-6-K 3-4-5-I 3-4-5-G	....	3-4 M	..	6 L
Hand screw machines	1-2-3 4-5-6 F	1-2-3 4-5-6 D	3-4-5 G	1-2-6-K 3-4-5-G	1-6-K 3-4-5-E	1-6-K 3-4-5-D	1-6-K 3-4-5-I	1-6-K 3-4-5-I	1-6-K 3-4-5-I	1-6-K 3-4-5-I	1-6 2-3-4-5 K	1-6-K 3-4-5-G	1-6-K 3-4-5 D	1-6-K 3-4-5 D	1-6-K 3-4-5-I	1-6-K 3-4-5-I 3-4-5-G	....	3-4 M	..	6 L
Auto. screw machines, single spindle	......	1-2-3 4-5-6 D	....	......	1-2-3 5-6 E	1-2-3 5-6 D	1-2-3 5-6 D	......	......	......	1-2-3 4-5-6 E	......	1-2-3 4-5-6 D							
Auto. screw machines, mult. spindle	......	1-2-3 4-5-6 D	....	......	1-2-3 4-6 E	1-2-3 5-6 D	......	......	......	......	1-2-3 4-5-6 E	......	1-2-3 4-5-6 D							
Semi-auto. chucking machines	1-2-3 4-5-6 F	1-2-3 4-5-6 D	.... 3-4-5 G	1-2-6-K 3-4-5-G	1-2-6-K 3-4-5-I	1-2-6-K 3-4-5-I	1-2-6-K 3-4-5-I	1-2-6-K 3-4-5-I	1-2-6-K 3-4-5-I	1-2-6-K 3-4-5-I	1-2-3 4-5-6 K	1-2-6-K 3-4-5-I	1-2-6-K 3-4-5-D	1-2-6-K 3-4-5-D	1-2-6-K 3-4-5-I	1-2-6-K 3-4-5-I 3-4-5-G	...	3-4 M		
Pipe cutters	3-6-F	3-6-F	3-6-G	3-6-G	3-6-G	3-6-D	......	......	......	......	3-6-G	3-6-G	......	......	......	3-6-G				
Bolt cutters	3-F	3-D	....	3-G	3-G	3-D	3-D	3-D	3-D	3-D	3-G	3-G	3-G	3-G	......	3-G	3-G			
Gear and thread hobbers	1-2-3 F	3-D	....	1-2-3-6 G	1-2-3-6 G	1-2-3-6 D	1-2-3-6 D	1-2-3-6 D	1-2-3-6 D	1-2-3-6 D	1-2-3-6 E	1-2-3-6 E	1-2-3-6 D	1-2-3-6 D	1-2-3-6 D	1-2-3-6 G				
Gear shapers	6-F	1-2-6-E	....	1-6-K	1-2-6-E	1-2-6-E	1-2-6-E	1-2-6-E	1-2-6-E	1-2-6-E	1-2-6-E	1-2-6-E	1-2-6-D	1-2-6-D	1-2-6-E	1-2-6-E				
Thread millers	3-F	3-D	....	3-G	3-E	3-D	3-D	3-D	3-D	3-D	3-E	3-E	3-D	3-D	3-D	3-D				
Vertical boring mills	1-2-3 4-5-6 F	1-2-6-K 3-4-5 D	4-5-G	1-2-6-K 4-5-G	1-2-6-K 4-5-G	1-2-6-K 4-5-G	1-2-6-K 4-5-I	1-2-6-K 4-5-I	1-2-6-K 14-5-I	1-2-6-K 4-5-I	1-2-4 5-6 K	1-2-6-K 4-5-G	1-2-6-K 4-5-D	1-2-6-K 4-5-D	1-2-6-K 4-5-I	1-2-6-K 4-5-I 4-5-G	....	4 M		

Horizontal boring mills	1-2-4 5-6 F	1-2-6-K 4-5-D	.... 4-5-G	1-2-6-K 4-5-G	1-2-6-K 4-5-G	1-2-6-K 4-5-I	1-2-6-K 4-5-I	1-2-6-K 4-5-I	2-6-K 4-5-I	1-2-6-K 4-5-I	1-2-4 5-6 K	1-2-6-K 4-5-G	1-2-6-K 4-5-D	1-2-6-K 4-5-D	1-2-6-K 4-5-I	1-2-6-K 4-5-I 4-5-G		4 M		
Planers and shapers	6-F	1-2-6-K																		
Vertical milling machines	6-F	1-2-6-K	....	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K			
Horiz'tal milling machines	6-F	1-2-6-K	....	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K			
Slotters and key seaters	6-F	1-2-6-K	....	......	......	6-E	6-E	6-E	6-E	6-E	6-K	6-K	6-E	6-E	6-E	6-E	6-E			
Drill presses	1-4-5-F	6-K 4-5-D	4-5-G	1-6-K 4-5-G	6-K 4-5-G	6-K 4-5-G	6-K 4-5-G	6-K 4-5-G	6-K 4-5-G	6-K 4-5-G	4-5-6-K	6-K 4-5-G	6-K 4-5-D	6-K 4-5-D	6-K 4-5-I 4-5-G	6-K 4-5-G	6-K 4-5-G	4 M		
Tappers	4-F	4-D	4-G	4-G	4-G	4-G	4-G	4-G	4-G	4-G	4-G	4-G	4-D	4-D	4-G	4-G	4-G	4M		
Internal grind'g mach.	6-J	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	....	6 C	6 C	6 C
Cylinder and horizontal	6-J	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	6-C	....	6 C	6 C	6 C
grinding machines	6-J	6-B	6-B	6-B	6-B	6-B	6-B	6-B	6-B	6-B	6-B	6-B	6-B	6-B	6-B	6-B	6-B	6 B	6 B	6 B
Lapping machines	6-J	6-H	6-H	6-H	6-H	6-H	6-H	6-H	6-H	6-H	6-H	6-H	6-H	6-H	6-H	6-H				
Honing mach.	6-J	6-J	6-J	6-J	6-J	6-J	6-J	6-J	6-J	6-J	6-J	6-J	6-J	6-J	6-J	6-J				
Broaching machines	6-F	6-D	....	6-D	6-D	6-D	6-D	6-D	6-D	6-D	6-E	6-E	6-D	6-D	6-D	6-D	6-E	6 E		
Power saws	6-K	6-K	....	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K	6-K			
Draw presses	......	......	....	......	......	......	......	......	......	......	6-G	......	......	......	......	......	6-G			
Punch presses	6-F	6-D	....	......	......	......	......	......	......	......	......	......	......	......	......	......	6-G			

Operations

1. Heavy cutting
2. Light cutting
3. Threading
4. Tapping
5. Reaming
6. General operations

Cutting fluids

A. Air
B. Soda ash—water—lard—light
C. Soda ash—water—lard—heavy
D. Mineral—lard oil—11 per cent
E. Mineral—lard oil—5.5 per cent
F. Kerosene—mineral oil—10.0 per cent
G. Sulphurized mineral oil—1 per cent S.
H. Sperm oil
I. White lead—lard oil—30 per cent.
J. Kerosene
K. Water emulsions
L. Vacuum
M. Petrolatum or cup grease.

affected, especially when only 5 to 10 per cent of lard oil is used in the mixture. This should be carefully watched where the mixtures are low in lard oil.

Precision reaming is one of the most difficult machine operations. A hand reamer, rotating in a turret lathe in which the centrifugal side play in the operation is minimized by a guide bar, is a good method. This guide bar maintains a uniform pressure throughout the operation and prolongs tool life. Mineral lard oil gives best results for this work, but general reaming may be done by using mineral oil containing sulphur.

Oils are messy, but in many operations they prove more economical than water compounds because they can be sterilized and used over and over again. By keeping close watch of the oils used and of the way in which the additions of lard oil are made, the efficiency of a department can be checked to a considerable extent. At the same time it is necessary to note the number of pieces secured per grind of the tools, as the cutting fluid plays an important part in tool life.

Fiber and similar material can be cut and threaded very satisfactorily by using petrolatum or ordinary cup grease as a lubricant. It can usually be applied by hand. Tearing of the fiber must be eliminated, and it is found that a negative top rake on the tool will help this.

Table XXXII which follows gives many suggestions as to the cutting fluid to be used under different conditions.

The best cutting speed for steels is governed by its hardness and toughness. Free-cutting screw stock such as cold rolled steel, can be cut at 140 ft. per minute, axle steel from 70 to 90 ft. per minute, and heat-treated steels from 45 to 60 ft. per minute. These are, of course, only fair averages. The feeds depend largely on the depth of cut, design of part, and finish desired. In the machining of large iron or steel castings more cubic inches per minute can be removed without distortion if the speed is reduced and the feed increased.

Terms Commonly Used in Connection with Cutting Oils

Baumé Gravity.—The gravity of an oil indicates the weight of a given volume at a standard temperature. The "Baumé" gravity is the system generally used in speaking of lubricating oils. On this scale the gravity decreases as the viscosity is raised so that when comparing gravities, care should be taken that the viscosities are relatively the same. Inasmuch as

the gravity of an oil varies according to the source of the crude from which it is refined, the gravity offers us the best index of the source of an oil.

Flash and Fire.—The flash and fire tests are generally indicative of the inflammability or, on the other hand, the resistance to heat of an oil. The flash point is the temperature at which sufficient vapor is given off to ignite momentarily and the fire point that at which continuous combustion is maintained. The Cleveland open-cup tester containing 60 cu. cm. of oil is generally used for tests of lubricating oil. As its name indicates, it is an open cup with provision for evenly heating the contents. A test flame is brought near the surface of the oil periodically and the flash and fire temperatures noted on a thermometer suspended so that the bulb is immersed in the oil.

Viscosity.—Viscosity is that property of an oil ordinarily spoken of as body. The Saybolt universal viscosimeter is used almost universally in this country for measuring the viscosity of lubricating oils. With this instrument the viscosity is expressed by the number of seconds it takes for 60 ml. of oil to flow through a standard orifice at standard fixed temperatures. For lighter viscosity oils the viscosity is generally taken at a temperature of 100°F., while in the case of the heavier bodied oils it is taken at a temperature of 210°F.

Cold Test.—Truly an important feature, the cold test of lubricating oils is frequently ignored by industrial buyers. The cold test of an oil is the test which indicates the temperature at which the oil becomes congealed to a point where it will not flow. There are several tests in use such as the solid test, pour test, cloud test, and cold test. In the laboratory method commonly used, the temperature of an oil which has been chilled to solidification is raised gradually until the oil will flow from one end of a four-ounce bottle to the other. The temperature at which this occurs is called the cold test.

Carbon Test (Conradsen).—This test does not occupy the position of importance it did before lubricating-oil-refining processes became as highly standardized as they are today. The Conradsen carbon test is a means of measuring the residual carbon. It consists essentially in heating a sample of the oil evenly in an enclosed vessel until all of the vapor has been driven off, and of weighing the residue. The carbon content of the products of the leading refineries is uniformly so low that aside from "sales talk" the theoretical difference in high-class oils means little to the consumer.

Color Test.—Colors are usually designated by the N. P. A. color number, ranging from water-white to No. 6 which is a dark red color. Very dark colored oils are tested mixed with kerosene or water-white naphthas. Bright clear lubricating oils irrespective of viscosity may be considered as more highly refined than oils of opaque cloudy appearance.

Saponifiable Content.—The saponifiable content of an oil is that part of it which will combine with a caustic to form soap. In general practice a sample quantity of the oil is boiled with a standard alcoholic solution of caustic potash and the excess alkali titrated with an acid solution. This test indicates the amount of fatty matter contained in a compounded oil.

Sulphur Content.—In sulphurized oils the sulphur content is, of course, an important feature. It is also somewhat difficult to determine it accurately.

Usually the bomb calorimeter or the bromine nitric acid oxidation test is used. In both of the above methods the sulphur is oxidized to a sulphate and this sulphate precipitated by well-known chemical methods. It is necessary to distinguish between sulphur in an effective form and that in neutral compounds such as sulphates which add nothing to cutting value.

Iodine Value.—This is a complicated chemical test generally applied to fatty oils, the purpose of which is to determine the amount of oxygen that the oil will absorb or whether it will become thick and gummy. A high iodine value means an oil that will dry with great rapidity and low iodine value means an oil that dries very slowly; for instance, linseed oil has a high iodine number. This oil first becomes gummy if exposed to the air, then finally forms a film over the surface. This is why linseed is used for a paint oil, where quick drying properties are essential. This quality in a lubricating oil would destroy its usefulness.

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